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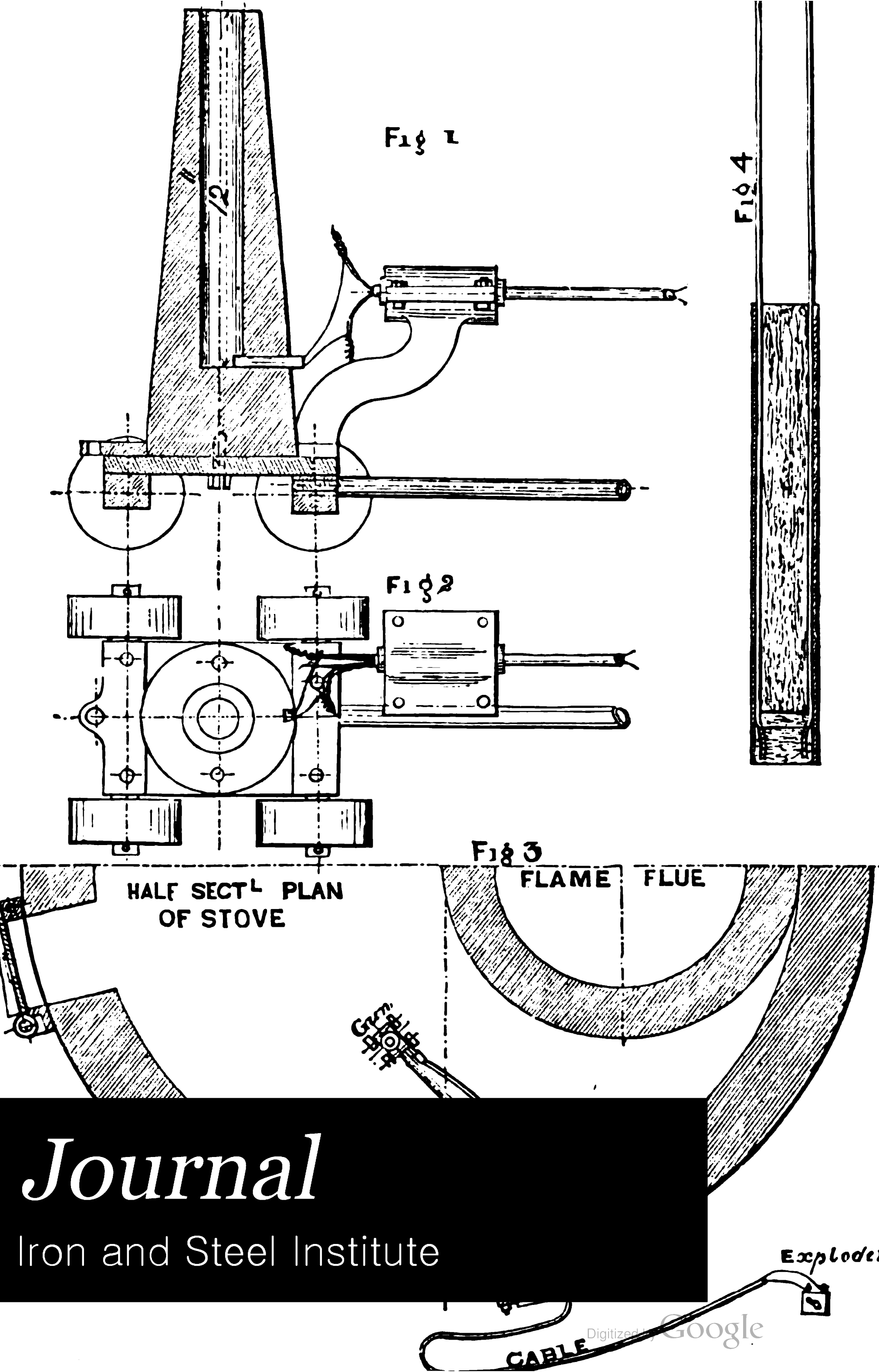
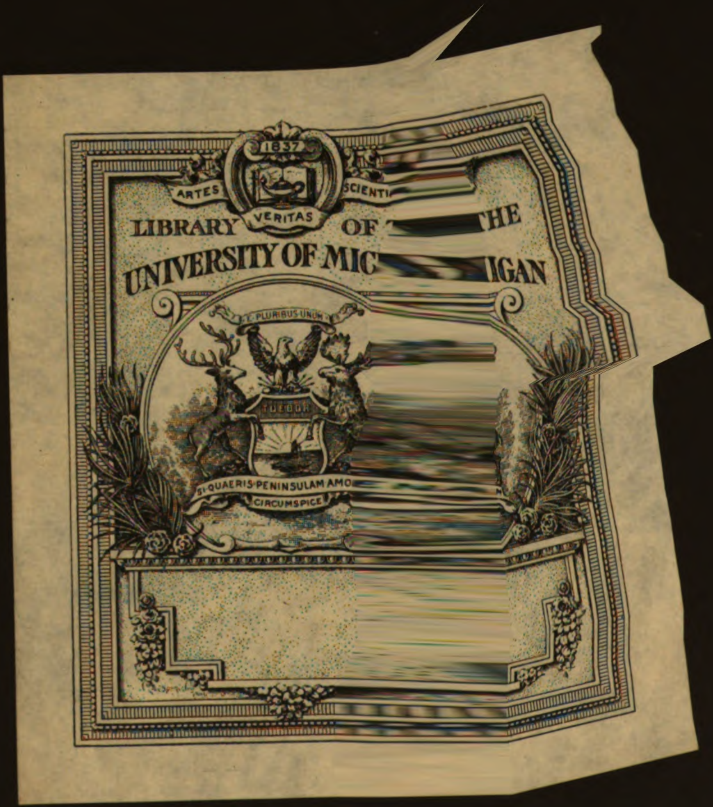
Journal

Iron and Steel Institute





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II.—1882.

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PROCEEDINGS

OF THE

IRON AND STEEL INSTITUTE.

VIENNA MEETING, 1882.

TUESDAY, SEPTEMBER 19th.

THE proceedings of the INSTITUTE were opened this morning in the Hall of the AUSTRIAN SOCIETY OF ENGINEERS AND ARCHITECTS, Eschenbachgasse, Vienna.

The SECRETARY read the following letter from JOSIAH T. SMITH, Esq., President of the Institute:—

"MY DEAR SIR,—I shall be obliged if you will communicate to the Council and members the fact that my medical men protest in the strongest manner against my attending the Vienna Meeting, and assure me that I would be certain to break down, followed, in all probability, by illness of a most serious character, if I were to do so. I venture to think that under these, to me, most painful and disappointing circumstances, it will be felt that I must submit to their opinion; and my only pleasant reflection in the matter is that I am sure the Institute will not suffer by my absence in the gentleman you may select to preside.—Yours faithfully,

"J. T. SMITH, *President.*

"J. S. JEANS, Esq."

Mr. THEODORE FRY, M.P., said they would all regret losing the company and chairmanship of Mr. Smith, who, in the usual course of things, would have presided over that meeting, and they would regret it all the more because his absence was owing to the unsatisfactory state of his health. He was sure they would all wish him a speedy recovery. They were, however, fortunate in having the presence among them of Mr. I. Lowthian Bell, a past President, who was perfectly able and willing to perform the duties of Chairman at that very interesting meeting. Mr. Bell's name was well known, not only in the iron trade of his own country, but also in Austria, and indeed he might say wherever the iron and steel industries of the world were carried on. He proposed that Mr. Bell should take the chair on that occasion.

Mr. Bell, having been voted to the chair, said he was sure no one could regret the absence of the President more sincerely than he did upon that occasion, because he found himself called upon at the eleventh hour to undertake what under any circumstances must necessarily be a very responsible duty. However, with the support of his colleagues in the Council and of the members of the Institute—whom he was glad to see present in such goodly numbers—he trusted to see the business of the meetings satisfactorily gone through. The Chairman then announced that the Statthalter of Lower Austria would welcome the Institute to Vienna on behalf of the Emperor. He would be followed by the Burgermeister of Vienna, who would welcome the Institute in the name of the city; and lastly, the President of the Austrian Society of Engineers and Architects would also address the meeting.

Reception of the Institute.

Herr C. August von Frey said that several months ago, when it came to be known in Austria that the Iron and Steel Institute would probably not object to hold their autumnal meeting in Vienna, the Austrian members of the Institute, and several other gentlemen connected with the iron industry, assembled to consider the best manner in which this proposition should be carried out. At that meeting it was unanimously resolved to send an invitation, and this was kindly accepted. A committee was formed, which consisted of gentlemen connected with the iron and steel industries, to organise a suitable reception. A number of other gentlemen, whose illustrious names would add *éclat* to the proceedings, became honorary members. It would be seen by the programme that the Government of the Empire of Austria was favourable to the meeting, that the authorities of the City of Vienna offered them their kind hospitality, and that the Society of Engineers and Architects of Austria had placed their rooms at the disposal of the Institute. All this hospitality, which was promised to the Institute, was but an acknowledgment of the kindness and good-will shown to the members of the Austrian iron and steel trades when they found themselves in England. The local committee in Vienna had been aided by local committees in Buda-Pesth, Leoben, and Graz. These committees had organised arrangements for excursions to their several localities, and would do their best to make those visits instructive and agreeable. He concluded by offering to the Institute, in the name of the Reception Committee, a hearty welcome to Vienna.

The STATTHALTER OF LOWER AUSTRIA (His Excellency Ludwig Freiherr Possinger von Choborsky) next addressed a cordial welcome to the Institute on behalf of the Emperor and Government of Austria. His Excellency said he had the honour to assure the members of the Institute, on the part of the Government, of their anxious desire to give every assistance for the furtherance of their meetings. For the first time the progress which had been made in the iron and steel industries of Austria would be described and discussed in a public meeting; and they hoped by the mutual exchange of ideas on the part of eminent scientific men, that not only would absolute knowledge be gained, but that an impulse would be given to the further development of the iron and steel industries, which were of so much importance in the economy of nations, and afforded the best guarantee for the prosperity of other branches of industry. The Austrian Government, therefore, had the greatest sympathy with any movement or occasion tending to raise the iron industry of the country, for their national wealth depended greatly upon that industry being carried on in a satisfactory and economical manner. The Government would follow the discussions on that occasion with attention, and would make use of any suggestions made by them so far as they might be based on practical experience. The interests represented by the Institute would be fostered by the Government, which would continue to do all in its power to advance and develop the iron and steel industries of the country. His Excellency, in conclusion, expressed a hope that the meeting might be successful, and that the members of the Institute would enjoy their stay in Vienna.

The **Burgermeister of Vienna** (Herr Edward Uhl) welcomed the Institute in the name of the City of Vienna. He assured them of the warmest sympathies of that city with the subjects of a great state joined by friendship to Austria, and pre-eminent as the pioneers of civilisation, and as representatives of the most important branches of industry in the world. The authorities would do all they could to make their stay in Vienna agreeable.

Herr C. **Pfaff**, the Vice-President of the Society of Engineers and Architects, in the unavoidable absence of the President (Herr C. Prennenger), welcomed the Institute on behalf of that Society. He said theirs was a technical scientific Society, and had the same object in view as the Iron and Steel Institute, viz., technical progress and perfection. He therefore might greet them as colleagues engaged in the same work. The Society's rooms and all their contents were at the disposal of their guests, and he expressed the hope that the members would feel themselves at home in them on that occasion, and that after their labours they would be able to spend some agreeable hours in the beautiful City of Vienna.

The **Chairman** said he had already bespoken the sympathy of the members of the Iron and Steel Institute in undertaking the duty which had been imposed upon him that morning. Fortunately for him, eloquent language was not necessary in order to return on their behalf, and on behalf of the Council, thanks to those gentlemen who had received them so kindly. Indeed, if he were to fail at all in this respect, he felt quite satisfied that their hosts would have ample opportunity afforded by individual members of judging how highly the extraordinary efforts made for the reception of the Institute were appreciated by those who had come so far to take a part in the present meeting. In common with those gentlemen who had just addressed the meeting, members of the Institute were impressed with the friendly nature of their present visit to the Austrian dominions. He earnestly hoped that the presence of the members of the Institute might be regarded as an indication of those feelings which up to this time had prompted sentiments of perfect friendship between the inhabitants of Austria and Great Britain. In fact, science and art knew no geographical boundaries, nor had they any nationality. It was a matter belonging to and interesting the world at large. They themselves, as an Iron and Steel Institute, had endeavoured upon a very early occasion in their history to bear witness to that being their feeling, for they had conferred the highest honour it was in their power to bestow upon his venerable friend, their countryman, Professor von Tunner (whom he was delighted to see among them), by awarding to him the Bessemer gold medal.

Speaking in German, the CHAIRMAN then proceeded to acknowledge the hearty welcome given to the Institute. He said he hoped they would excuse his addressing to them some words expressive of their thankfulness for the reception they had met with in the same tongue in which the representatives of the highest authorities in that mighty realm had welcomed them on the occasion of their friendly visit to that beautiful city. He was requested by his colleagues on the Council of the Iron and Steel Institute to assure them that they knew how to appreciate the kind reception they had received. So far as it was permitted to them individually as well as to their Institute, which occupied itself with the improvement of a peaceful art, it was their most sincere and heartfelt desire that the results of their visit might be to unite still more closely the two mighty nations joined together already by so many ties of mutual friendship.

The minutes of the previous general meeting were then read, approved, and signed by the Chairman.

Election of the President-Elect.

The Chairman then announced that the Council of the Iron and Steel Institute had unanimously decided to recommend the name of Mr. Bernard Samuelson, M.P., as the President-elect, in succession to Mr. Smith.

On the motion of Mr. Windsor Richards, the meeting unanimously confirmed the recommendation of the Council.

Proposed Alteration of Rule 10.

Mr. D. Adamson gives notice, in accordance with the requirements of Rule 20, that at the next annual meeting of the Institute he should propose that such part of Rule 10 as specifies that the President shall be elected for two years shall be cancelled, and that instead of the words, "the President shall be elected for two years," shall be substituted the words, "the President shall be elected for one year."

New Members.

Messrs. John Corner and F. Dale Banister were elected scrutineers of the voting papers, and reported, on the completion of their scrutiny, that the following candidates had been elected members of the Institute:—

Abbot, Benjamin A.	Stockton.
Baldry, James D.	London.
Bowman, Harold	Manchester.
Boyd, A. C.	Dukinfield.
Bunter, James C.	Glasgow.
Butlin, William	Wellingborough.
Cavendish, Lord Edward, M.P.	Chatsworth.
Chapman, John G., jun.	Darlington.
Church, Richard F., M.I.C.E.	Westminster.
Cole, Charles	Brierley Hill.
Cosgrove, John	Birmingham.
Davies, William H.	Pontymister, Mon.
Davis, John B.	Bilbao, Spain.
Eagland, W.	Ardsley.
Evans, Christmas	Wales.
Firth, Lewis J.	Sheffield.

Fowler, Edmund	Birmingham.
Freir, William E.	London.
Fromm, E.	Bavaria.
Galloway, Arthur Walton	Manchester.
Gjers, Lawrence F.	Middlesbrough.
Greene, Robert R.	Dublin.
Hannah, Joseph	Carlisle.
Haswell, Charles J. F.	Vienna.
Hay, Alexander S.	South Hampstead.
Horton, John R.	Shifnal.
Hunt, John	Sheffield.
Lennard, John M.	Middlesbro'-on-Tees.
Marié, Marcus	Westminster.
McNay, Thomas F.	Westminster.
Moore, William	Brigg.
Morgan, Thomas	Ohio, U.S.A.
Neilson, Hugh, jun.	Mossend, N.B.
Neilson, John A.	Coatbridge, N.B.
Palchondhuri, B.	Ipswich.
Parkes, Henry P.	Tipton.
Patchett, James	Wellington.
Pearce, William	Glasgow.
Pirie, Lewis J.	Clapham.
Rasche, Ludwig	Aix-la-Chapelle.
Russell, John	Westminster.
Smith, George J.	Sheffield.
Solens, H.S.H. Prince Albert	Prussia.
Spencer, John	Sheffield.
Thompson, James	Kendal.
Thompson, Andrew Green	Cockermouth.
Thomson, James A.	Dumbarton, N.B.
Wallis, Henry Ellis	Westminster.
Wilkinson, George	Tipton.
Williams, William	Swansea.
Wilson, Robert	Carlisle.
Wittgenstein, Karl	Vienna.
Woodall, John W.	Scarborough.
Wylie, Alan C.	London.

The following paper was then read:—

ON THE IRON INDUSTRY OF STYRIA AND CARINTHIA.

BY P. RITTER VON TUNNER, LEOBEN.

OUR distinguished guests from England, the members of the Iron and Steel Institute, on visiting the ironworks of Styria and Carinthia, may possibly be disappointed in their expectations. They may, perhaps, find less progress in the manufacture of iron than they had expected. I thus feel myself in a manner bound to give a short account of the situation occupied by Styria and Carinthia, as a defence for those members of the profession of the land of my birth, to whom neglect and insufficiency might be imputed.

It is well known that the Styrians and Carinthians compete for the questionable honour of having made from their iron the nails with which the Divine Founder of our holy religion was crucified. The excellent quality of the Noric iron was known to the Romans, and the iron mountains near Eisenerz and Hüttenberg belonged to the Roman province of Noricum.

No doubt both Styria and Carinthia are amongst the oldest iron-producing countries of Europe, their iron mountains being unsurpassed for the abundance and quality of their ores, as well as for their still extant forests. These circumstances would certainly lead us to expect a far more advanced state of the iron industry in the countries in question. This expectation appears to be still more justified when we take into consideration that the Government has for years taken active measures not merely to encourage the industry, but also the science of metallurgy. In Styria especially, the local legislators did most in this way, and were further encouraged and supported in their efforts by His Imperial Highness the Archduke John, whose memory will always be held dear by the Styrians. The province of Styria, more than fifty years ago, took measures to found a perfectly independent school for instruction in the metallurgy of iron. These endeavours were carried out in 1839, when a mining school was opened at Vordernberg, which developed in course of time into the Mining Academy of Leoben. At this school special importance is still attached to instruction in the metallurgy of iron. The very first school for instruction in iron manufacture was founded at Fahlun, in Sweden, under Professor Sefström, but to my certain knowledge Vordernberg was the second; for in the older schools of Freiberg in Saxony and Schemnitz in Hungary, very little attention was paid to instruction in this branch of learning.

We may now well inquire how it is that Austria, and in particular Styria and Carinthia, are so far surpassed by England, Germany, and even by Belgium and France, not merely in the output of iron and the cost of production, but even to some extent in quality. Many reasons can be given, but the following are the principal:—

1. It is generally known that the last-named countries have an abundance of first-rate mineral fuel. Delivered to the ironworks at a relatively low figure, this fuel can be used in all reverberatory furnaces with scarcely any preparation, while it can also be used in the blast furnace, either as it comes from the pit, or after being coked, at very little cost.

On the other hand, the Austrian Alpine districts of Styria and Carinthia are mostly confined to the use of the much more expensive vegetable fuel, spread over a wide area, and in many cases obtainable in a comparatively limited quantity only. It is true, indeed, that Styria in particular possesses a by no means small quantity of mineral fuel. But with the exception of small amounts of impure coal of older formation in the western, and an equal amount of coking coal in its southern districts, it is all a thin sort of brown coal and lignite. These cannot be used without admixture in the blast furnace; and as regards the reverberatory furnace, such fuels must be prepared, either by a drying process, or by being resolved into gas.

It must be allowed that Styria has not been inactive in endeavouring to diminish the disadvantages under which it labours as to mineral fuel. In no country have more experiments been undertaken in this direction. The use of brown coal and lignite for working the blast furnace was actually first carried out in Styria, and also the gasification of brown coal for melting cast steel in the Siemens furnace, as proved at the London Exhibition of 1862. Both Styria and Carinthia have tried to raise the production of pig iron by importing coke from Moravia and Hungary. This method of working must, however, be obviously restricted by the high railway freights.

Bohemia, Moravia, and Silesia are better situated as to fossil fuel, so that in future the Alpine countries will not be able to compete with them, either in quantity or in price, but must try and assert their superiority in the quality of the iron they produce. I am convinced they will assert and maintain this superiority, in spite of the dangerous competition caused by the dephosphorising process now in use by the above-named countries. Within certain limits, however, it is to be expected that the exchange of good ores from Styria, with good coke from Moravia and Bohemia, now partly begun, will extend in the future, if the railway authorities take into consideration the general advantage, and indeed their own profits.

It is also to be remarked that the inland competition by exchange, so to say, is a great advantage for Austria. It should obviate the necessity of facilitating the foreign competition, to avoid monopoly prices for iron in Austria.

2. The cost of producing iron in the Alpine districts is furthermore materially increased by the expense of carriage; for quite apart from the high railway tariffs, the cost of transport in those mountainous districts is necessarily very high. On account of the more or less steep inclines of the railway lines and roads, only one-half, and often only one-tenth of the load can be transported with the same power as on level lines. The cost of production in the Alpine countries must thereby be materially influenced. This may be illustrated by the fact that to produce one hundredweight of bar iron, it is necessary to transport ore, flux, fettling, pig iron, and other materials to the aggregate amount of five to ten hundredweights on average distances.

Another not unimportant cause which raises the price of production in the Alpine districts lies in the relatively high cost of labour, the heavy taxation, and the high rate of interest paid for money. On account of the sterile nature of mountain soil, provisions are expensive, and the fact that the greater part has to be brought from long distances also raises the price of labour.

Similar loss is induced by the numerous Roman Catholic holidays and Saints' days, which are not kept, as in other Catholic countries, for twelve hours, but, according to ancient usage, for thirty-six hours, the ordinary Sundays included; and, besides, many of the holidays fall in the middle of the week. The reasons for the high rate of interest paid for money, as well as the heavy taxation, are too well known to need further elucidation, and means to reduce these burthens are not within reach of the ironmasters. I cannot refrain from adding, that in such naturally poor countries as the Alpine districts, the higher the rate of interest, the more difficult and expensive is it to raise capital for reconstructing old works or erecting new ones; and yet, with the immense changes that have succeeded each other during the last twenty years in the manufacture of iron, such alterations were obviously necessary.

3. One important reason why the manufacture of iron has made relatively so little progress in our Alpine countries lies in the very fact that this industry has existed so many centuries, and has thus consequently become so much divided in regard to the ownership. Owing to this, a great many diverging tendencies and customs injurious to trade have sprung up, which, though antiquated, are difficult to remove. The following personal experience may serve as an illustration.

In the years 1830 to 1840 I attempted by my pen, as well as by lecturing, to bring about a combination of the ironworks of Upper Styria. My notion was to erect rolling mills in common, to be enlarged later on by adding puddling furnaces, with the object of using the brown coal near Judenburg for the whole of the works. Whenever the question was debated with the separate proprietors, every man was in favour of the idea, but as soon as it came to a general meeting, their diverging tendencies prevented a final decision. When in 1840 the Government bought up the coalpits at Fohnsdorf, and began to erect large rolling mills and puddling furnaces in the vicinity, it was again the proprietors of the small ironworks round about who prevented them being carried out. They stormed the authorities with petitions not to ruin their interests. The Government gave way to them, and, transporting to Reschitza, in Hungary, the plant already delivered, they erected the works there. Now that a fusion of the principal ironworks of Styria and Carinthia has taken place under the Austrian Alpine Mining Company, matters will improve, a proper division of labour can take place, a saving in the cost of transport will result, and instead of continual disagreements, the works will help each other.

Wherever the necessary natural supplies exist as a basis, it is much easier to erect works in an entirely fresh district than in places where a large industry has existed for ages. A notable example is the flourishing condition of the ironworks of Westphalia, which has been arrived at in a comparatively short period.

4. Though the Alpine countries are not alone in being affected by the inefficiency of the laws for the protection of the iron industry, still I would also allude to this point. There is no doubt that in the same measure as a too high import duty which excludes all competition is an injury to trade, so too low a duty (if any at all is necessary) prevents any trade from prospering. There is no doubt that not merely the Alpine districts, but the whole of Austria, need protection for their iron trade, and particularly against England and Germany. I am sure that to no Austrian, having the interest of his country at heart, is it immaterial whether it has an iron trade or not; the only question in doubt is the proper amount of protection required. During the last twenty years, the iron trade here has not suffered so much by a too low rate of import duty, but rather from the manifold exceptions and evasions that have been made in the protective laws. The repeated changes in the rate of import duty have had the worst possible influence upon trade. They have induced a want of confidence, and capitalists have therefore been afraid of investing. Strong

and healthy plants will sometimes thrive on bad land, but in quicksands no plant at all can grow.

If the above-named disadvantages with which the iron industry of the Austrian Alpine countries have had to contend are considered, you will perhaps be less disappointed with the state you find it in, and possibly form a more favourable opinion of it. Far from maintaining that the arrangements and working are perfect, I am sorry to say that many an improvement and innovation, the advantages of which were generally acknowledged, could not be adopted from actual want of capital. Some half-finished undertakings near Leoben may serve as an example. Another instance of how divided ownership and the accompanying divergence of interests mar all efforts at improvement may clearly be seen in the manner in which the coal is transported at Seegraben, near Leoben.

Taking it in a general way, however, the Alpine countries, using vegetable fuel, such as lignite and turf, in their iron manufacture, have attained such a position as enables them to hold their own against any other country compelled to use the same kind of fuel.

The mining as well as the transport of the ore on the well-known two large iron mountains in Styria and Carinthia you will find very well organised. You can also convince yourselves how much has been done of late for the cultivation of the forests, and that the charring of the wood, at least in the principal places, is done in the best way possible. In no country is the production of charcoal iron carried on either so extensively or so perfectly; and it is only to be regretted that the erection of one large blast furnace, begun at Vordernberg, has not been completed.

The Austrian Alpine countries were also the first to produce ferromanganese direct from the blast furnace. This was carried out by the Carniola Iron Company. The priority was proved at the Vienna Exhibition of 1873. Many of the old refining works still existing, whose production is confined to a small quantity of steel for special purposes and to refined iron for wire and plates, are worked according to the most perfect principles, with a view to the utmost possible saving in charcoal. In the puddling process, the fuel used is lignite, the residue of peat and wood burned upon a step-grate, or is used in different kinds of gas furnaces, which have since served as patterns for other places. On the Continent, Styria and Carinthia were in 1862 the first to adopt and improve the Bessemer process. In connecting it directly with the blast furnace, the Austrian Alpine countries were even before England, though the priority is due to Sweden. To my certain knowledge, also, the use of the Siemens furnace for puddling and welding was first tried in Styria. Cast steel was also first produced from the Siemens furnace at Kapfenberg, in Styria; and I believe that the production of Bessemer metal by direct connection with a Siemens furnace was first carried out at Neuberg, in Styria.

What is likely to create an unfavourable impression upon the minds of the members of the Institute when they visit the Alpine ironworks, and compare them with the extensive ironworks in England and other countries where pit-coal is employed, is not so much the size and extent of the works, but the relatively small production. However, this is the consequence of being principally dependent upon vegetable fuel. Wherever such fuel is used, the ironworks are generally so arranged as to make numerous different kinds of iron and steel. Therefore, when you contrast the Alpine ironworks with the ironworks of other countries, I would beg you to compare them with countries which are dependent upon the same kind of fuel.

In conclusion, I would say a word as to the reason why England surpasses the Austrian Alpine countries, even in part, in the good quality of its iron. Before England began to import a large quantity of ores from foreign countries, its superiority in quality was confined to the better kinds of cast steel, and to particular kinds of soft iron, very uniform in grain. This could only be attained by using the best Swedish iron, and by the great care observed for many years in the manufacture of cast steel. Add to this, also, the excellent quality of the fuel used, whereby the highest temperature can be easily obtained. England has not only gained great advantages by the magnitude of its production, which allows a thorough method of sorting, but has also been able, by a suitable division of labour, to educate a superior class of workmen.

England has also in the course of time introduced certain methods in the fabrication of particular kinds of metal, such as producing a special iron for making a better quality of tin plates, and the method used at Lowmoor and Bowling for producing a first-class homogeneous welding iron, &c., &c. Altogether, however, these specialities have been confined to small quantities, and those at very high prices. But since England imports about 2½ million tons annually of the best iron ores from Spain, Algiers, Italy, and Russia, the superiority in the quality of its iron has been increased still further. This is felt all the more, as the cost of the first-rate pig iron made from these ores in England is about 25 per cent. lower than the price at which it can be produced in our Alpine countries.

Apart from the cheapness of the fuel used, the reason of this surprisingly cheap production of pig iron from foreign ores in England lies in the circumstance that, in spite of the long water-carriage, the cost of the ore, delivered to the iron-works, is seldom higher than 9½d. per hundredweight. With such an immense production, also, as in England, trade expenses, and even labour, are less than in the Alpine countries.

No doubt the dephosphorising process will in a measure contribute to the superiority of English iron. However, as England, though using the Thomas-Gilchrist process, instead of importing less, continues to import more foreign ores, and still increases its demand for hematite, although it is so high in price, there can on this account be no great danger for the Alpine iron trade. Through experience we know—and I would particularly refer to the United States of America—that charcoal iron, which is produced at a not too high temperature of blast, is purer and less mixed with foreign substances than iron produced from fossil fuel at a high temperature of blast. Accordingly, for certain purposes there is always a demand for charcoal iron, and it is always worth from sixpence to one shilling more per hundredweight than coke iron. This advantage will, therefore, always remain to the Alpine iron trade.

In all sincerity and gratitude, I acknowledge you, our honoured members of the profession from England, as our teachers and masters in iron manufacturing. It would be surprising if such were not the case. England produces about twenty times as much iron as Austria; therefore it may be assumed that twenty times as much brain-work is employed in the English iron trade as in the Austrian. Financially and commercially England has certainly more than twenty times the amount of power to rely upon.

The CHAIRMAN said those members who had accepted the kind invitation of their Leoben and Graz friends would see for themselves the conditions under which pig iron was manufactured in the Vordernberg Valley. Undoubtedly the materials were of the highest degree of excellence, and the fuel, being charcoal, was very dear. Much had been done in order to enable the ironmasters of that district to derive the greatest possible benefit from those materials, and they would see in the paper itself that not only had Styria taken a leading part in producing very good iron, but she seemed also to be the first place in Austria where the then new process of Bessemer was put into practice. They might well ask by what course of events that had taken place. For his own part, he could only ascribe it to the careful study which every matter connected with the manufacture of iron had received at the hands of the Metallurgical School of Leoben; and he believed that to no one was the iron trade of Austria more indebted for what it had learnt in respect of these matters than to Professor Tunner. He had, therefore, much pleasure in proposing a cordial vote of thanks to their venerable friend and honorary member for the paper to which they had just listened.

A vote of thanks was then passed by acclamation to Professor Tunner for his valuable paper.

The next paper read was :—

ON THE IRON INDUSTRY OF HUNGARY.

By A. RITTER V. KERPELY, BUDA-PESTH.

THE metallurgical industry of Hungary may be said to be quite as old, and, at the present time, at least quite as fully developed, as that of the neighbouring States lying to the west and to the south-west. At a depth of about a foot from the surface of the ground, in the midst of beautiful vineyards, remains of iron slag have been found, which show that centuries ago, and notwithstanding the 150 years' dominion of the Turks, iron was produced in Hungary by the methods then in vogue. Even in the time of the Romans, in the first century of our era, the excellent iron ores of Hungary were mined not far from the famous Trajan road and the Român colonies lying near thereto. There are, indeed, written descriptions extant of the working of iron mines in Upper Hungary in the years 1326 and 1408, especially in the district of Gömör and Zips. In the latter year reference is made in a lawsuit to the Dobschauer ironstone mines and works lying along the rivulet of the Göllnitz, as being old-established even then. But the great antiquity of the iron industry in any country cannot, of course, be regarded as in any sense a criterion of its subsequent progress and present state of development. On the contrary, we find that the iron manufacture of Asia, which was carried on 1500 years before the Christian era, has, in the subsequent 3500 years, made practically no progress whatever; while the iron industry of Europe, which is of much more recent origin, has, as we may without hesitation affirm, arrived at the highest stage of development. But even throughout Europe, this development has not proceeded by regular gradations, but has, in some cases, influenced by some sudden or exceptional impulse, made rapid and enormous strides. In countries with more limited means of production and inferior demands, it has not been easy to follow the improvements and innovations that have been made from time to time in the technology and practice of the iron manufacture; and hence, without absolute retrogression, they were in such a position that they could only very gradually avail themselves of such progress. In Hungary, the conditions requisite for the successful prosecution of the iron industry were not always the most favourable, notwithstanding the extensive and excellent deposits of iron ore of which the country is possessed. The difficulties in the way of obtaining the necessary supplies of suitable fuel have in Hungary, as in many other countries, and especially in the neighbouring States, tended to hinder the development of the iron trade; and although we have now arrived at a knowledge of how to meet our necessities in some degree by the successful use of inferior qualities of fuel, the absence of fuel supplies of a better description still remains a great hindrance to the extension of our metallurgical industry.

The largest, if not also the most important, section of the iron trade of Hungary is compelled to use vegetable fuel for the smelting works, of which we have now altogether forty-eight erected, possessing sixty-eight blast furnaces. Of this number, only one works, Reschitza, uses coke; one other uses coke and coal, Kalan; another uses charcoal and coal, Anina; one uses one-half charcoal, Theissholz; and the remainder use only charcoal, chiefly made of beechwood.

The ironstone deposits of Hungary, in regard to their richness, variety, and extent, are not inferior to those of the most highly favoured of neighbouring States. Spathic iron ore deposits and masses of considerable thickness and extent are found in the districts of Gömör, Zips, Abanj, Torna, Sohl, Liptau, and Szörény. The Dobschauer Erzberg (iron mountain) with its numerous deposits, which, in some places, run to a thickness of 36 metres, and even more, yields ores, mainly worked in the open, which have a content of 2 per cent. to 4 per cent. of manganese, and 36 per cent. to 42 per cent. of spathic iron of great purity and value. On one side of the Dobschauer, along the valley of the Sajo, and on the other side along the valley of the Gölnitz, there are numerous spathic and brown iron ore deposits, quite as important as those of the mountain itself, and developed to an even larger extent. Of late years much importance has been attached to the spathic and brown iron ore deposits of the Zipser district, especially in the vicinity of Kotterbach, owing to the export trade with Upper Silesia. These deposits likewise furnish to the works in Trzynietz (in the Austrian part of Silesia) the greater part of their iron ore supplies, from their own mines in the Zipser district. In the districts already named, and in most of the iron-ore-bearing districts of Hungary, there are brown and spathic iron ore deposits, in some cases intermixed with red iron ore. The mine of Gömör near Röcze, which yields porous brown hematite partly in the state of powder containing 40 per cent. to 61 per cent. of iron (brown ore), has an extent of 4½ kilometres and a thickness of 4 to 37 metres.

The Salgo-Tarjan-Rima Muranyer Company, the Royal Works, Heinzelmann, and several other smelting works of limited extent, have in this district their most considerable mines. The first-named Society is connected to the Erzberg by a rope tramway 15 kilometres in length with its projected new smelting works, and undertakes the duty of transporting the iron ore of the Royal Works for Theissholz as far as the regular railway.

Another considerable deposit of brown and red iron ore, which has not yet been fully opened out, is found in the Borsoder district, near Telekes and Rudobánya.

The iron and steel works of Witkowitz, in Moravia, have joined the Erzievier, of which it has acquired a lease from the State, by a narrow-gauge railway, with the Bánréve-Feled railway by Barczika, and a considerable development of mining enterprise has thus been brought about in this district, 600,000 Zoll. centners having been worked during five months of the year 1881.

Of greater importance to the iron trade of Hungary than any of those already named are the mines in the Hunyader district, which contain extensive deposits of brown iron ore, merging, in some cases, into red. With partial interruptions, these deposits are known to extend for a distance of more than thirty kilometres. At Gyalar, which is the property of the State, the principal deposit reaches a thickness of a hundred metres. The ore is almost entirely free from impurity, and in the lower deposits it has a content of 3 per cent. to 8 per cent. of manganese, with 41 per cent. to 50 per cent. of iron. It is smelted by the Royal Works in Govasdia in charcoal blast furnaces.

The scarcely less important deposits of the Kronstadt Company, which are also worked in the open, belong to the same series, and are smelted partly at the works of Kalan and partly at the works of Ruszkitza.

Magnetic iron ore, which is found in pockets of large dimensions, is chiefly smelted in the blast furnaces of the State Railway Company at Reschitza, and the other works in that neighbourhood. Ores of this class are also found near Theissholz in Gömör, near Metzenseifen, in the Zipser district, and in the Maarmaroscher district, partly alone, and partly in admixture with other ores. Red hematite of the most remarkable purity is the material chiefly employed in the blast furnaces of the Gömör district. Analyses of ores of this class will be found in a work published by the writer in the year 1876, and entitled "Eisensteine u. Eisen Erzeugnisse Ungarns" (The Iron Ores and Iron Productions of Hungary). From these analyses it will be seen that some of the Upper Hungarian spathic and brown iron ores contain copper, but, by a careful separation of the copper contained in such ores, there is no difficulty in using them for the manufacture of pig iron of high quality, and they are actually so used, more especially when exported. Phosphorus is found only in a few of the deposits of the Gömör district. The greater part of the ore is so pure that it can be used for the production of the best brands of Upper Hungarian iron. Sulphur is contained in some of the ores of Hungary, chiefly combined with barium, which, whether existing in veins or diffused throughout the mass, can be separated without difficulty.

The smelting works of Hungary have become accustomed to respond to the demands for their pig iron, and can, considering the materials they require to employ, produce iron of a very excellent quality. Seeing that the fuel used, as already stated, consists chiefly of charcoal, the future of the

Hungarian iron industry must depend upon the production of iron of superior excellence, all the more so as it is becoming necessary to bring the charcoal from still greater distances to the works, and the cost of production is thus materially enhanced. To the increasing difficulty of procuring supplies of charcoal must be attributed the fact that the export of iron ores from Upper Hungary has so greatly augmented, until it has now reached a total of about 2,500,000 Zoll. centners per annum. The most important smelting works of Upper Hungary, especially those of Count E. Andrassy, with five blast furnaces, those of the family Sarkany, with three blast furnaces of their own and two others taken on lease, the two blast furnaces of Smizsan, and the two blast furnaces of Krompach, draw a great part of their supplies of charcoal from the Zemplin and even from the Marmaros districts, the distance varying from 300 to 380 kilometres. For the two Royal blast furnaces in Theissholz in the district of Gömör, a part of the charcoal supplies for the current year will be taken from the Ungher district, a distance of 280 kilometres.

To the facilities accorded for the transport of the raw materials required, and the desire of the Hungarian State Railways to facilitate the development of our iron industry, must be attributed the fact that the charcoal can be brought from such long distances with advantage, notwithstanding the relatively low prices of our pig iron. The State Railways have provided a description of waggon specially adapted for the transport of charcoal, each waggon being equal to carrying 100 metrical centners, and grants for long distances low rates of freight, which are not at all below the well-known special tariffs of England and Germany.

Notwithstanding that the forests in the near neighbourhood of the ironworks are now very much reduced in bulk, and in some cases entirely exhausted, there is not, so far, any reason to complain of the scarcity of charcoal in Hungary; but the distance of the available forests from the centres of the iron trade naturally increases from year to year, and all the more so as the industry becomes more fully developed. In order to give some idea of the extent of forest lands still left in Hungary, I may mention that the State forests alone extend over an area of 1,726,500 hectares. The different forest lands belonging to the Church represent a further area of 58,433 hectares. The private estates of the State Railway Company in the district of Krasso extend over 88,000 hectares; the forests of the Duke of Coburg in the Gömör and Zipser districts extend over 49,500 hectares; the forests of Count Emanuel Andrassy in the district of Gömör cover 19,567 hectares; those of the Salgo-Tarjan-Rima-Muranyer Company, 18,992 hectares; and those of the Nadrager Iron Company, 12,058 hectares; while if the remaining forest lands of the various parishes and private owners are taken at 575,500 hectares, the total extent of woodlands in Hungary will reach a total of at least 2,530,000 hectares. The annual consumption of timber from this area of forest land is 14,000,000 cubic metres, and if only one-third part of this total were utilised for metallurgical purposes, it would represent annually a production of ten million Zoll. centners of charcoal pig iron. In spite, however, of the enormous resources of our forest lands, in most of the ironmaking districts the scarcity of proximate fuel-supplies is becoming more and more felt, owing mainly to the fact that most important and valuable forest lands lie in mountainous districts almost impossible of access, and at a great distance from rivers, streams, and roads adapted for transport. The fact that these forest lands are practically unavailable for the iron industry is a matter of great public importance, and steps have been taken by the Hungarian Ministry of Finance to furnish a proper solution to the problem thus presented.

For the supply of two blast furnaces which are now being built in the Vajda Hunyad the necessary supplies of charcoal will be brought direct from the locality where the fuel is prepared, situated at a distance of thirty kilometres, in the midst of otherwise inaccessible beech forests, by a rope tramway with four stations, to the furnaces.

It is not necessary to go at greater length into the advantages of being able to bring the charcoal directly from the forests to the blast furnaces, thus avoiding the losses caused in transport, the crumbling of the fuel, and the bringing about of the most complete utilisation of the forest lands.

The management of the ironworks of Hungary is now, with few exceptions, in the hands of technically educated and practically skilled men. It would not be possible otherwise, at the present day, to meet the requirements of our iron and steel works.

The practical results obtained in the carrying on of our chief iron-making establishments are, on this account, extremely satisfactory. There are works in Hungary, as, for example, those of the Salgo-Tarjan-Rima-Muranyer Company, which produce 100 kilos. of pig iron with not more than 4 hectolitres of beech charcoal, being 83 per cent. of the weight of the iron made. The works of Andrassy in Gömör produce 100 kilos. of pig iron with 4·5 to 5 hectolitres of charcoal. The Royal Ironworks in the Govasdia-Hunyad district use only 4·5 hectolitres of charcoal per 100 kilos. of pig, and the Royal Works of Theissholz, in the district of Gömör, consume only 4·6 to 5 hectolitres of mixed hard and soft fuel. The works of Reschitza, again, in the district of Krasso, use only 5·2 hectolitres of beech charcoal per 100 kilos. of iron made. The production of these smelting works varies per blast furnace from 6000 to 10,400 Zoll. centners (300 to 520 tons) per month, according to the dimensions of the furnace and the character of the iron being made.

These results, highly favourable for Hungary, are owing chiefly to increased height of the blast furnaces, which are now raised to 14 metres, the widening of the bosh and the mouth, and the increased pressure and temperature of blast, which have become general.

At the works of Count Andrassy the blast is now heated from 300° to 400° C. At the Royal Ironworks of Theissholz two blast furnaces have been fitted with three Whitwell hot blast stoves, each 8 metres in height by 5 metres diameter, wherewith the blast is raised to a temperature of 500° C., and it is hoped that by the use of these stoves a still further increase of production and economy of fuel will be attained.

In all the Hungarian pig iron works, the surplus gases from the furnaces are utilised, and when water is the main motive power employed, they are employed for reheating, and for the raising of steam in the boilers, which have within recent years been erected at most of the smelting works.

At the present time Hungary possesses an aggregate of forty-one pig iron works, with fifty-two blast furnaces in operation. The yearly production of the whole country amounts to 3,350,000 Zoll. centners, of which 352,000 Zoll. centners take the form of castings.

These figures are not likely to suggest to English, French, and German metallurgists that our iron industry is one of any great importance. Our trade, in point of fact, is entirely a home one, and does not go beyond the supply of our own every-day requirements, in respect not of crude iron alone, but of railway material and machinery as well, for the manufacture of which considerable contracts have been concluded.

The manufacture of finished iron is carried on in Hungary, with but few exceptions, in the ordinary puddling furnace, a fact obviously indicating that very few of our ironworks are engaged in the manufacture of rails, tyres, axles, and other railway *materiél.* Most of our works, indeed, have been compelled to direct their attention mainly to the production of such articles as an almost purely agricultural country like Hungary specially requires, and in reference to which they are threatened on all sides by competition.

It will be sufficiently manifest that the use of charcoal as a fuel in the puddling process is not likely to assist the iron industry of Hungary, having regard to the conditions of the fuel problem already referred to. The smaller ironworks, indeed, where the ordinary system of puddling is employed, subject to these conditions, have been obliged to succumb to the competition of the larger and more important works, which within the last few years have adapted the Siemens regenerative gas furnace to their requirements, and have thus averted a catastrophe which, with the continued use of vegetable fuel, it would otherwise have been impossible to avoid.

The immediate occasion of the introduction of the regenerative gas furnace was the favourable results obtained by the Siemens furnace at the works of Salgo-Tarjan, in the year 1877, with brown coal of inferior quality. The adoption of the regenerative gas furnace at these works brought about a remarkable economy in the consumption of fuel, the production of the works having more than doubled relatively to the cost of the fuel employed. Nor could the improvement of the product remain unnoticed by manufacturers and others who were interested in the development of the trade. Hence we find that in Brezova (Royal Works), at the beginning of the year 1879, the use of undried uncut wood was attempted in connection with the regenerative gas puddling furnace. In Ferdinandsberg, the works of the Kronstadt Mining and Metallurgical Company, there are five gas double-puddling furnaces fired with wood, and three welding furnaces in Bujakova, the works of the Prihradny Iron Company, are similarly worked; and so with the works of Kudsir (Royal Works), where there are two double gas puddling furnaces and two gas welding furnaces.

The timber employed as fuel, mostly beechwood, is often introduced directly after the felling into the producers, which have the appearance of pits below the ground-level; but, notwithstanding this, the consumption of fuel per 100 kilos. of iron produced has been reduced at Brezova from 0·6 and 0·7 cubic metres (210–245 kilos.)—which was the average of the old furnaces—to 0·25 and 0·4 cubic metres (88–140 kilos.); and in Bujakova the consumption has fallen from 0·41 c.m. (173 kilos.) in the old furnaces to 0·2 c.m. (70 kilos.) in the regenerative gas furnaces now employed.

If the iron is suitable, containing 0·5 to 0·6 per cent. of silicon and very little graphite, the waste is on an average not more than 3 per cent. When making fibrous iron from cast iron of proper quality, this waste is reduced to 1·5 per cent. or 1·0 per cent., and often disappears altogether.

The charge of pig iron used in Brezova amounts to 550 kilos., and in Bujakova it is about 500 kilos. Six charges can be worked in twelve hours.

The greatest obstacle hitherto found to lie in the way of working regenerative gas puddling furnaces successfully arises, as is well known, from deposits of iron oxide in regenerative chambers, which render it necessary to have many stoppages in order that the chambers may be cleaned out. This difficulty, however, is entirely obviated in the gas puddling furnaces of Brezova, Bujakova, and Kudsir. These furnaces are constructed of exceptional length instead of being made in the form of a horse-shoe; and to facilitate the operation of puddling, two fire-bridges are provided, at short distances from each other, and so arranged that all dust falling between them will be smelted and can be taken away. The adoption of this simple arrangement has allowed the puddling process to be carried on almost without interruption in the furnaces employed at the three works I have named. As an example of this continuity of working, it may be stated that at Brezova three puddling furnaces were regularly in operation for a period of three months without any necessity arising for cleaning out the regenerators.

With the gas welding furnace in Brezova the quantity of wood consumed per heat has fallen from 0·6–0·7 to 0·17 and 0·35 cubic metres (210–245 to 60–123 kilos.)

Notwithstanding that such favourable results have been obtained by the use of gas made from timber in the production of wrought iron, mineral fuel is increasingly employed. The refining works in Reschitza, Anina, Osd, Diósgyör, Salgo-Tarjan, and Kalan use mineral fuel exclusively. At Reschitza and Anina, which are possessed of excellent coal-supplies, direct firing is employed both in the puddling and in the welding furnaces, of which there are twenty-five and forty-one respectively. The works of Salgo-Tarjan, Diósgyör, Osd, and Kalan, which have coal-supplies of an inferior quality, have made arrangements for regenerative gas heating. The achievements of Salgo-Tarjan as the pioneer of this movement have been frequently referred to in metallurgical literature, and are, therefore, tolerably well known. The solution of this important question was, indeed, an essential condition of existence, not only to Salgo-Tarjan, but also for the other works named, which have each in their way made great efforts to establish the success of puddling by the use of regenerative gas furnaces.

At the present time there are in operation the following works using regenerative gas furnaces fed with brown coal, viz.:—

Salgo-Tarjan,	with	10	double puddling	and	7	reheating furnaces.
Diósgyör,	„	2	„		4	„
Osd,	„	11	„		5	„
Kalan,	„	3	„		2	„
Total,	.	26	„		18	„

In a shift of twelve hours, a gas puddling furnace will produce six to eight charges of 500 to 600 kilos., with on an average from 3 per cent. to 4 per cent. of waste, and uses for every 100 kilos. of rails, 160 kilos. of brown coal in the generators, and 90 kilos. under the boilers. In Salgo-Tarjan 300 to 350 kilos. are used with direct firing.

In localities lying at a considerable distance from the coal deposits, such as the works of Brezova, Kudsir, and Bujakova, they have, by improving their direct firing arrangements and by the introduction of coal gas producers and Bicheroux firing, made it possible to use with success coal imported from very long distances.

Thanks to the improvements and achievements we have now described, not less than to the advantageous rates of freight conceded by the Hungarian State Railways, the iron trade of Hungary has now obtained complete possession of the home market, and it has also been able to make considerable progress in the manufacture of tin plates and merchant iron.

So far as regards the manufacture of steel, it is, as we have already indicated, carried on in Hungary in only very few works, but still in a creditable manner. The works of the Royal State Railway Company in Reschitza, with four converters and two Siemens furnaces for making Siemens-Martin steel, occupy, as is well known, a respectable position in the steel industry. At these works, during 1881, 610,800 Zoll. centners (30,540 tons) of steel ingots were produced, of which 390,000 centners were used for rails, 24,500 centners for tyres, 8300 centners for axles and plates, and 2900 centners for merchant steel.

The stagnation in railway construction which set in after the year 1873 was not encouraging to those who projected new steelworks in Hungary, any more than in other countries, and it was not till three years ago, when railway enterprise became more active, that it was deemed desirable to commence the construction of steelworks at Diósgyör. Here a Bessemer works, answering all modern requirements, has just been completed and will shortly be at work, while two open-hearth furnaces have been working for a year past.

The pig iron required for the manufacture of steel is mainly produced in the ironworks of Upper Hungary. To melt the pig iron required for the Bessemer process gas furnaces have been erected, as all coke requires to be imported from Silesia and Moravia, while the brown coal of our own districts, which resembles ordinary lignite, can be used for the gas furnaces. The furnaces at Diósgyör have been constructed by the State, and promise to meet the current requirements of the State Railways. It forms an integral part of the State machine-works at Buda-Pesth, whence the bridge-building works will be transferred to Diósgyör.

In Brezova there is an open-hearth furnace for the production of castings and tin plates.

Of puddling and other steel about 5000 Zoll. centners are produced yearly in Hungary. Crucible steel is only produced at Kudsir and in Prackendorf; in the former about 500 Zoll. centners, and in the latter about 200 centners per annum.

The crucible smelting oven in Kudsir was, until recently, supplied with the Ponsard recuperator; but as soft kinds of steel in the heating with gas from timber could not easily be made to smelt, it had to be removed, and replaced by a Siemens regenerative furnace.

As in all countries which are compelled to use vegetable fuel, there are in Hungary a large number of small smelting and other works in out-of-the-way places; and although a single block-furnace is still worked with perseverance in a district in Transylvania, I believe I have said enough in this roughly sketched picture of our iron industry to show that we are striving to keep pace with our western and south-western neighbours in the race of progress.

APPENDIX.

I.—ANNUAL PRODUCTION OF PIG IRON AND CASTINGS IN HUNGARY.

DISTRICTS.		Blast Furnaces.		Production in Cwts.	
		In Blast.	Out of Blast.	Pig Iron.	Castings.
Resitza	K.k. priv. Staateisenbahngesellschaft	4	...	560,000	30,370
Bogschan		1	...	85,100	...
Dognatska		2	...	89,440	...
Anina		2	...	137,340	56,940
Röcze	Salgo-Tarján-Rimamurányer Verein	3	...	360,000	20,000
Nyustya		1	...		
Tiszolcz	Ung. Staats-Eisenwerke	2	...	156,240	1,238
Libétbánya		1	...	32,082	1,854
Govasdia		1	...	101,824	3,216
Fehérpatak		1	6 months	11,637	7,852
Rójahida		1	3 months	4,236	6,108
Rhónitz		...	...	...	11,320
Diósgyör		...	1	...	12,480
Ruszkitza	Kronstädter Bergbau- u. Hütten-Actien-Verein	2	...	135,000	15,000
Lunkány		1	...	27,000	...
Kalán		1	1	200,000	28,000
Csisnoviz	Heinzelmann	2	...	50,000	60,000
Nadrág	Nadráger Eisenindustrie-Gesellschaft	1	1	31,600	18,500
Oláhpatak	Graf Emanuel Andrássy	1	...	360,000	...
Alsó Sajó		1	...		
Betlér		2	...		
Gombaszög		1	...		
Csetnek (Concordia)	Sárkány'schen Erben	2	...	45,000	15,000
Henzko		1	...	70,000	...
Csetnek	Madarász	1	...	24,000	6,000
Unter-Metzenseifen	Ganz u. Comp.	1	...	26,000	...
Krompach	Krompach-Hernalder-Eisengewerkschaft	1	1	34,000	23,000
Prakendorf	Graf Ladislaus Csáky	1	...	24,000	8,000
Strazena	Herzog-Coburg-Kohári	1	1	98,000	...
Pohorella		1	...	30,000	1,200
Rothenstein		...	1	...	...
Dernö	Graf Dionis Andrassy	1	...	27,500	13,500
Göllnitz (Marienhütte)	Karl Ménesdorfer	1	...	30,000	...
Hámor	Ottokar Takobs	...	1	...	...
Szmizsán	E. Prihradny (Pächter)	1	1	60,000	...
Ober Remete	Graf V. Sztáray	...	1	...	...
Altwasser	Gedeon und Comp.	1	...	30,000	...
Antalocz	Béla Botka u. Gera	1	...	12,000	...
Dobschau	Brüder Sárkány (Pächter)	2	...	60,000	...
Dreiwasser	Pribradnischen Erben	...	1	...	..
Wagendrüssel	Scholtz	...	1	...	...
Munyásza	Graf Waldstein	1	...	20,000	...
Restirata		1	1	12,000	...
Vaskoh	Groswardeiner Bisthum	1	...	10,00	...
Ploszko	Ploszkoer Verein	...	2	...	...
Gerlicze	Gerlicze Tapolcsaner Verein	...	2	...	...
Szalocz	Szaloczer Gewerkschaft	1	...	40,000	6,000
Szentkeresztbánya	A. Hrobony	1	...	10,000	7,000
	Total	52	16	2,997,999	352,540
	Total tons			150,000	17,600

II.—ANNUAL PRODUCTION OF FINISHED STEEL AND IRON IN HUNGARY.

DISTRICTS.		Number of			Production in cwts.				
		Puddling Furnaces.	Frisch feuer.	Heating and Welding Furnaces.	Iron and Steel Production.		Tin.	Wire.	Total.
Resitza	(7 Converters, 2 Siemens Furnaces) Kk. priv. Staatseisenbahn Gesellschaft	11	...	40	73,300	426,320		...	523,000
Anina		14	...	15	120,540	...	...	...	120,540
Salgó-Tarján	Salgó-Tarján-Rimamuránjer Verein	10	...	7	370,000	...	...	30,000	400,000
Ozd		11	...	5	300,000	...	...	...	300,000
Nadasd		...	...	16	...	...	70,000	...	70,000
Brezova	(1 Siemens Furnace) Hungarian State Ironworks	6	...	7	66,186	...	24,100	...	90,286
Pieszok		1	...	1	31,810	...	...	...	31,810
Quatimech		1	...	5	730	1,338	9,338	...	11,406
Vajszkova		1	1	1	4,138	...	...	...	4,138
Kudsir		3	1	4	18,750	3,562	...	...	22,312
Kabolapojána		1	1	2	4,826	...	...	...	4,826
Rójahida		...	1	...	1,680	...	...	...	1,680
Diósgyör	(2 Converters in Construction)	2 (Siemens 2)	...	4	80,720	22,920	...	...	103,640

Ferdinandsberg	Kronstädter Bergbau u. Hüttenactien Verein	7	...	3	100,000	...	20,000	...	120,000
Ruszkberg		...	6	1	33,000	...	...	...	33,000
Kalán		3	...	2	70,000	...	...	...	70,000
Bujakova	Prihradny-Gewerkschaft	5	2	5	96,000	...	4,000	...	100,000
Nadrág	Nadrâger Eisenindustrie Gesellschaft	7	...	2	25,000	...	20,000	...	45,000
Krompach	Krompach-Hernálder Eisenw. Gesellschaft	...	1	...	...	...	4,000	...	4,000
Prakendorf	Graf Ladislaus Csáky	...	5	...	7,000	200	11,600	...	15,800
Kapsdorf	Herzog Coburg-Kohári	...	...	5	16,000	...	...	...	16,000
Poharella		...	...	3	12,000	...	9,000	...	21,000
Zavadka		...	...	2	6,000	...	...	...	6,000
Rothenstein		...	...	3	...	...	...	...	...
Zlatno		...	...	4	...	...	...	...	...
Ober und Unter Svabolka		...	...	2	...	...	18,000	...	18,000
Göllnitz (Marienhütte)	Karl Ménesdorfer	...	...	...	12,000	...	...	...	12,000
(Mathildenhütte)	Ottokar Jakobs	...	2	...	3,000	...	...	...	3,000
Hámor			1						
Ober Remete	Graf v. Sztáray	2	1	4	16,000	...	...	...	16,000
Altsohler Blech-, Walzwerk	Gesellschaft "Union"	5	3	3	...	...	72,000	...	72,000
Antalocz	Béla Botka u. Gera	1	...	2	5,000	...	...	...	5,000
St. Keresztbánya	A. Hrobony	...	4	...	5,000	...	...	...	5,000
	Total	48	29	148	1,475,680	454,340	285,418	30,000	2,245,438
	Converters	4							
	Martin furnaces	5							
	Total tons	...	...	...	73,784	22,717	14,270	1,500	112,271

The **Chairman** having invited the opinions of the meeting, and no one responding, said that in point of fact neither of the two papers just read really admitted of much discussion, as they were purely historical. He would ask Mr. Kerpely, however, at the proper time for a little explanation on two points. They were told that in the two gas-welding furnaces the consumption of fuel had fallen from 0·6 to 0·7 cubic metres. Englishmen did not know much about the measuring of fuel by bulk, and perhaps Mr. Kerpely would put it in weight, and that would give the members a better idea of the actual quantity consumed. Some members might suppose that the improvements and achievements spoken of in the paper were less due to other circumstances than to the advantageous rates of freight conceded by the Hungarian railways. He dared say some ironmasters would be glad to compare the rates in Hungary with other countries. Perhaps Mr. Kerpely would give at the same time the rates of carriage for manufactured iron; so that English members and those of other nations might compare them with the prices paid by themselves.*

The following paper was then read:—

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* It will be noted that the author has since given the weight as well as the bulk of the fuel consumption referred to in his paper. The actual rates of freight, however, he does not think it necessary to quote.—Ed.

ON THE MANUFACTURE OF STEEL WITH BROWN COAL AT TEPLITZ (BOHEMIA).

BY K. WITTGENSTEIN AND A. KURZWERNHART, TEPLITZ.

THE tertiary deposits of the north-west part of Bohemia, which extend from the Bavarian-Bohemian frontier to the east of the Fichtelgebirge, from the entrance of the Eger into Austria along the rapidly falling south-east edge of the Erzgebirge, are known by the name of the Bohemian brown coal basin. This basin is divided into several smaller basins, of which the most important is the so-called Aussig-Teplitz-Saezer basin, the length of which stretches from south-west to north-east about sixty kilometres, while the breadth varies from twenty-five to four kilometres, and is on the whole larger in the southern than in the northern part. The thickness of the principal deposit varies from ten to thirty metres, and in some places there is a thickness of even thirty-eight metres. The depth of the deposit never exceeds 200 metres, the average being about 100 metres; and in some places it is so near to the surface that it can be easily worked in the open.

The quantity of ash contained in the brown coal varies from 6 to 8 per cent., the content of water ranging from 15 to 20 per cent. About 200 kilos. of this brown coal are equivalent to one cubic metre of soft wood. The price of this coal, on account of the nearness of the deposit to the surface and the thickness of the bed, is very low relatively to that of the mineral fuel raised from the ordinary coalbeds in Austria, the average price per ton being 1 gulden o.w. (paper currency) to 1·20,—that is, from 1s. 6d. to 2s. per ton. The proximity of the river Elbe is attended with much advantage in the working of these deposits. The development of coal-mining operations in this basin is, however, of comparatively recent date.

Mining, in the true sense of the word, can only be said to have commenced in the year 1858, but since that date the trade has increased with such rapidity, that in the year 1881 no less than 6,000,000 tons were produced, of which by far the larger quantity was transported to Germany, both by railway and by the Elbe.

The existence of the brown coal deposits of this district, and of the means of economical transport of English iron from Hamburg *viâ* the Elbe, led in 1873 to the establishment of a Bessemer works and rolling mill near Teplitz, which, since 1881, has carried on the manufacture of Bessemer steel by the basic or Thomas-Gilchrist process. The arrangements of the Teplitz works differ in some particulars from those of other works of the some character, because they have been specially adapted for the use of Bohemian brown coal as a fuel, and because this point has been particularly kept in view in their construction, so as to enable the use of coke, which is exceedingly expensive in Bohemia, to be entirely dispensed with.

So far as concerns the manufacture of basic steel with Bohemian brown coal, we can only here refer to the *modus operàndi* of dealing with the heating of the metal, as the rest of the process does not differ materially from that usually followed in ordinary Bessemer practice. Our remarks will, therefore, be confined to the arrangements and manipulation adopted in heating the furnaces and converters employed in the heating of the lime and the spiegeleisen, the melting of the iron to be used in the converters, and, finally, with the employment of brown coal in the raising of steam.

In heating the Bessemer converters and the reheating furnaces, there is one and only one respect in which brown coal does not answer all the requirements of the process, and here we find the necessity for supplementing the use of brown coal by a fuel possessed of a larger flame. The brown coal has the peculiarity of giving up its heat—the least heat at the actual point of combustion—and for this reason a small quantity of coke must be used to aid in heating. It is necessary with the converter to have the interior sufficiently warm directly at the point on which the material rests, and which, on account of the application of the blast, is partly exposed to a cooling influence.

Experience has shown that it is not possible by the use of brown coal alone to get the bottom of the converter sufficiently warm. At Teplitz much value is attached to the duration of the converter bottoms for as long a period as possible, and it is usual after each cast to push out on an average two to six acid tuyeres, which is found to be attended with advantage to the duration of the bottom, as it is thus made impossible for any deep channels to be formed.

It will be understood that on this account the top of the converter bottom will become rather cool, as the material that has been introduced, which is generally acid (*quartz chamotte*), allows the steam to escape when the converter is again heated, thus lowering the temperature of the fuel at the bottom of the mass.

The gases produced from the brown coal rise naturally, and are only completely consumed when they reach the highest part of the pile, where they also heat the surrounding walls of the converter, while the lower part, and especially the surface of the converter bottom, remains cold and almost black. For this reason, after each charge, and after changing the tuyeres, 7 to 8 kilos. of coke are thrown into the converter, and afterwards 150 kilos. of brown coal are added. The coke, which has a short flame, delivers its heat directly on the surface of the converter bottom, and this has the effect of thoroughly drying and burning the mass that has been rubbed round the tuyeres as well as getting the bottom part of the converter to a white heat. With this kind of fuel the converter can, in five minutes' blowing, be made sufficiently hot to commence the treatment of the pig iron. We do not, however, mean to say that it is not possible, by way of exception, materially to shorten this time, if it is found necessary in practice.

The ordinary method of manipulating the ladle in Teplitz requires some coke to be used also for heating. With one casting ladle in Teplitz, 120 charges, and, under favourable circumstances, even twice that number of charges are cast without changing the ladle. In this way the casting hole is inserted from inside, and the ladle is cooled after each charge with water. This process is effected in the following manner:—

The workman throws into the casting hole of the ladle a handful of clay, after which the hollow ladle is filled with water. After the ladle is thoroughly cooled in this way, the new casting hole is put in. It is natural that the porous walls of the ladle should in this way absorb a great deal of water, and the short time which is available to allow of the heat being got up again makes it desirable that the best and most effective fuel should be employed. Hence it is that we always introduce about five kilos. of coke, along with about two baskets of brown coal. For every other purpose, however, brown coal alone is employed.

We will now proceed to speak of the method used for the heating of the spiegeleisen and the lime. Both of these operations are carried out at Teplitz at the same time, and with one and the same fuel. The lime is heated only with the surplus heat escaping from the heating of the spiegeleisen. The spiegeleisen is introduced, not in a liquid, but only in a very hot condition. We endeavour, as far as possible, to apply the spiegeleisen in a non-liquid state; and with the exercise of a little care on the part of the workman, it need never happen that the spiegeleisen causes any considerable ebullition in the converter; while, on the other hand, the temperature of the spiegeleisen is already so high that it is only a very little short of liquidity.

Although the low temperature attained by this mode of working is attended with disadvantage in some respects, it has, on the other hand, the compensating benefit that the whole manganese content of the spiegeleisen is called into requisition. We may add that a highly heated instead of a liquid spiegeleisen tends to further the uniformity of the steel. For the purpose of merely heating the spiegel as described, the brown coal is sufficient, without any application of gaseous fuel, and it even gives a sufficient surplus to bring the lime to a yellow heat.

The furnace used to heat the spiegel and lime is generally furnished with a direct step-grate firing, for the heating of which only nut coal is used. This coal costs about 8 kr. per 100 kilos. at the works.

It is necessary to specify here the various kinds of coal used at Teplitz according to their composition and quality. By *nut* is meant the coal in which the smallest pieces have a content of ¾ cubic centimetre, the largest a content of 36 cubic centimetres. The next smallest kind is called *lösche*, and it contains all that is smaller than nut coal, as well as all the dust that is gathered from the sorting of the coal. After nut coal, the largest is nut coal No. 2, which contains pieces of over 36 cubic centimetres to something under the size of a man's fist. Nut coal No. 1 contains only pieces of the size of a man's fist and over. Coal of a larger size is not used at Teplitz.

The spiegel is heated in a furnace resembling a welding furnace, which ends in a *fuchs*. The *fuchs* leads into a tower of a square section, in which there are several shelves, one above another on opposite sides, and inclining towards each other, on which the lime is placed. The tower terminates at the top in a firebrick chimney. Directly in the lower part of the chimney, the lime is introduced through a side opening, which leads downwards from one shelf to another towards the bottom, and finally covers the whole, so that the surplus heat must rise through the different layers of lime.

As Teplitz does not prepare its own lime, but procures it already burnt, it happens that there is often a great deal of fine slaked lime, in order to prevent which from adhering to the shelves, and thereby diminishing the draught of the furnace, vertical openings are provided in the sides of the tower, through which the surplus heat escapes, if the lime does not allow sufficient scope for this purpose, so that the due amount of draught required for the heating of the spiegel is not wanting. It will be easily understood that in the latter case the lime is not so fully heated as it should be. This arrangement of heating the spiegel and the lime at the same time has given very satisfactory results. For the heating of the spiegel and the chalk, 20 kilos. of nut coal are used. A charge of 6½ tons of pig iron—the usual charge for rail steel—requires an addition of 370 kilos. of spiegel and 600 kilos. of lime.

The most important use of brown coal is that of smelting the pig iron, for which, at Teplitz, the Siemens gas regenerative furnace is employed. The usual charge in this furnace amounts to 6½ tons of pig iron. The length of the furnace is 3·8 metres; the breadth, 2·0 metres; the extent of the surface available for the bath covers the full breadth of the furnace hearth; but the length is only 3 metres, the greatest depth in the centre of the furnace being 0·3 metres.

The gas and air chambers are arranged underneath the furnace hearth, thus giving upright generators. The cubical contents of a single air chamber is 15·5 metres, and those of a single gas chamber 14·5 centimetres. For the reversing valve cast iron cross valves are generally employed.

Such a furnace melts in two hours a charge of the proportions already described, so that eight charges in twenty-four hours can easily be obtained, including casting and re-charging. With these furnaces, by the acid process, with iron tolerably rich in silicon, and with 50 per cent. steel scrap added, the time occupied in heating a charge was not longer, and the iron ran exceedingly hot from the furnace. The fuel used to raise the heat in this case is also nut coal, but there are two methods of applying the fuel. The gas generators of the old furnaces have generally grate bars, while the newer generators are fitted with the step-grate. With the latter it was intended to use nut coal No. 2, which is produced in some districts, and which is between coal slack and nut coal No. 1. The nut coal used with the flat grate bars was liable to fall through, whereas with the step-grate excellent results are obtained.

Endeavours have been made to get up the necessary heat by means of slack with the step-grate, which, on an average, only costs 1½ kr. per 100 kilos., and in this direction considerable success was obtained, but the production was sensibly diminished, and for this reason the use of slack has been abandoned. The total extent of grate-bar surface in one furnace is 5 to 8 square metres. The layer of fuel has, in the generators with the glut-grates (*Planröstem*), a medium height of 0·8 metres, while with the step-grate generators the corresponding thickness is 0·52 metres. The gas collected from the generators is conveyed to a reservoir constructed of sheet iron, which is open towards the bottom, and stands in a cast iron water basin, wherein a great part of the tar, water, and flue dust is allowed to fall. In consequence of the large quantity of water contained in the Bohemian brown coal, such an arrangement for condensation is regarded as necessary. The gas is conveyed direct from the connecting-basin to the gas-valve, and the draught is so regulated that the gas in the furnace has a pressure of under one atmosphere, so that the flames are never allowed to appear outside the inspection holes of the furnace; while, on the other hand. air is drawn in from the outside. The furnace is supplied with a very strong draught, which enables the best result to be obtained. If the gas is allowed a pressure, as is the case so generally in the Siemens furnace, it not only does the work of smelting more slowly, but it also threatens to attack the chamber.

These furnaces require for 100 kilos. of iron 45 kilos. of nut coal. The smelting chamber is in all parts constructed with Dinas bricks, and the fire-bridges are kept in order during the working of the furnaces as required, loss of time from stoppages being as far as possible avoided. In the same way the side walls of the furnace are repaired. Each furnace will last about 600 charges, but after that time the hearth has become so broken up that a complete and thorough running out of the furnace cannot with safety be attempted. It is, therefore, preferred, after the furnace has stood about 600 charges—that is, after three months of regular wear—to construct a new furnace. In order to heat the iron with advantage, it is necessary to provide a chimney of 1·5 m. diameter and 45 m. high for every two furnaces. According to the character of the heating furnace, the iron heated with brown coal in the Siemens furnace undergoes some change in its chemical composition. Formerly, while the acid process was in use, one description of iron, introduced into the furnace with about 2·5 per cent. of silicon, was found, after being melted, to have its content of silicon reduced to 2·25 per cent., so that there was a considerable variation in the silicon content. With the basic process the content of manganese is varied in a much greater degree, one kind of iron, which, before being melted, contains 2·0 per cent. of manganese, showing a content of not more than 0·6 as it runs from the furnace.

It may finally be remarked, that the total quantity of steam required to be raised on the works is obtained from brown coal, and for this purpose only coal-slack is employed. In the consumption of this fuel, we use partly Bolsano's patent shelf-grates and partly step-grates, either system being found equally successful.

The Teplitz works require for the carrying out of the basic process about 20 charges of 6 to 6½ tons daily, about 1320 cubic metres of brown coal, and 1·6 cubic metres of coke, so that the quantity of coke required is only 0·1 per cent. of the total fuel employed. Brown coal, therefore, is used almost exclusively for the carrying out of this process.

DISCUSSION.

Mr. **Percy C. Gilchrist** opened the discussion, remarking that Mr. Cooper, himself, and a friend had spent the last week in visiting some of the basic works in Germany and Austria, and amongst those works was Teplitz. They found that these works were turning out more basic steel to-day than they did acid steel two years ago, and this was done, too, with an old plant. The machinery was less costly, but the work turned out would certainly compare well with the work done in England. With a plant consisting of only two converters, they were making 3000 tons of steel per month. One of the most interesting things there was the basic brick bottom, which lasted sometimes from thirty to forty charges. They had tried in England several times to make this kind of bottom, but they had not gone the right way about it, viz., by building the bricks in a special manner. In making the bottoms at Teplitz, the acid tuyeres were inserted in an inclined position, and two rows of basic bricks were built flat, and one row on end, but following the inclination of the tuyere and the joint. Whole butt-head bricks only were used, the big end downwards for this top course, no cement being used in building. The advantage of that principle of building in bricks was well illustrated by their former acid practice; for they were told that the average number of blows per acid bottom was one hundred, a number that had never been reached in England, where fifteen blows per bottom was considered good acid practice. With regard to the composition of the pig used, this agreed with what they were told throughout Germany, viz., that Ilsede pig was perfection. Ilsede pig contained, as they would remember, 3 per cent. of phosphorus, from 2 to 2½ per cent. of manganese, ½ per cent. of silicon, and under ·10 per cent. of sulphur. Here, as in Germany, the importance of manganese in the pig was insisted upon; they liked to have at least 1 per cent. of it, and preferably 2 to 2½ per cent. The average percentage of sulphur at Teplitz was ·08 per cent. The highest percentage of sulphur they would care to use was ·25; the highest they had ever used was ·45 per cent. Although the basic pig iron used here and elsewhere in Germany was called a white iron, the term was misleading, as the iron contained 2½ per cent. of manganese. In England they knew white iron to be a pig containing somewhere about 3 to 4 per cent. of metalloids, excluding carbon, while this pig that they called white iron contained 5½ to 6 per cent. of metalloids, so that it was really more than white iron. Still it had some characteristics of white iron, as the production per week from a blast furnace was greater when making this kind of pig than when making hematite iron. The consumption of spiegel or ferro with the Ilsede class of pig was much less than with a pig lower in manganese.

Perhaps the most striking thing, next to or before the bottom practice that they saw at Teplitz, was the question of scrap. They not only used the necessary amount of lime, but in a charge of 6½ tons of steel they carried from 400 to 800 kilos. of cold scrap; and it was put in, not by turning down the vessel, but by a slung hand-shoot when the vessel was blowing and vertical, the amount being regulated by the heat of the flame, and the greater part being added during the afterblow. That was really 8 to 16 cwt. of cold scrap per 6½ tons of steel.

They had also at Teplitz an excellent general mill for rolling rails, wrought iron sleepers, and plate blooms—the latter not being hammered but simply rolled. He thought the authors were to be congratulated on their very able paper.

Herr **Paul Kupelwieser** said the basic plant at the Witkowitz works had been burnt down some months ago, and they had now rebuilt their plant with vessels on Holley's removable-shell patent, but this system had been in operation only about a fortnight. He might say that they had used the bottoms for a very long time; and though at present he had not reliable statistics on the subject, he thought it would not be difficult, with the improvements now adopted, to make thirty charges per day.

Mr. **Windsor Richards**: How many tuyeres would you change?

Herr **Kupelwieser**: I think forty charges would consume about forty tuyeres. We do not change so many as at Teplitz, because we would rather change the bottoms.

Mr. **Windsor Richards**: How many tuyeres are in the bottoms?

Herr **Kupelwieser**: Witkowitz has only four, while Teplitz has six tuyeres in the bottom.

Mr. **Windsor Richards**: They would be changed ten times over. That is an important point.

Mr. **Jeremiah Head** (Middlesbrough) remarked that he had not intended to take part in the discussion of this paper, as, in all pertaining to steel-making, he considered himself a learner rather than a teacher. By the kindness of Herr Kupelwieser, he had, however, just been allowed to spend a couple of days at Witkowitz, and had there seen the rolling of basic steel plates in full operation. It might interest them if he briefly described what he had observed. The Witkowitz Company had a very fine plate-mill, with which they seemed to be rolling iron and basic steel plates indiscriminately. He found that the basic ingots were heated in ordinary mill furnaces fired in the ordinary way, and they seemed to come out at about the same heat that would be used in England for iron piles,—that was to say, at welding heat. As far as he could gather, there seemed to be no greater risk of spoiling these blooms by over-heating than in the case of iron. The ingots, when wheeled into the mill, were charged into a first heating furnace, and when they had attained about the same temperature as an iron pile would be heated to, they were brought out and cogged down in a Belgian or universal mill. This universal mill had the effect, firstly, of taking off the taper from the ingot both ways; and, secondly, of reducing it in thickness and elongating it in length. The cogged bloom so obtained was then cut hot into lengths, according to the weight of the plates required. If the bloom was not cut—or the pieces, if cut—it was then re-heated and passed first through the roughing and then the finishing plate rolls. There did not appear to be any material difference in the way of treating these in the rolls, as compared with the usual way of dealing with iron piles, except, perhaps, that less screw was given at each pass. The engines were of the reversing kind, geared in the proportion of 1 to 2½. They had plenty of power, and they worked very rapidly. The setting down of the screws was done by a small pair of engines on a pedestal, with a special man to work them, so that the roller had nothing to think about but getting the plate through backwards and forwards as quickly as possible. The man at the top had his orders to turn the screws a certain fraction of a revolution for each pass, the proportion diminishing as completion was approached. There were live rollers both front and back of the rolls to facilitate the getting in of the pieces very quickly; and there seemed to him in working down to be a much greater number of passes than would have been the case in dealing with iron. The piece, when entering the roughing rolls, was about 5 inches thick, and it was worked down to whatever gauge was required. The ingots that he saw passing into the Belgian mill after the first heating were on the average about 18 inches broad by 1 foot thick by 4 feet long. He examined several plates after they were rolled, and they certainly looked almost perfect. The Belgian mill had given them very good edges, so that they needed very little to be sheared off at the sides. Surface defects were very rarely to be found. The plates seemed to him extremely soft. He saw a piece ¼ inch thick taken indiscriminately from the scrap at the shears, and, without being heated, bent double, and then again bent double crosswise, without failure. They were also making tube strips, that was, strips about 12 feet long by $\frac{1}{4}$ inch thick and 9 inches broad, for turning round and welding into locomotive boiler tubes. He was informed that there was no difficulty in welding these tube strips. What he saw was extremely interesting to him, as demonstrating, firstly, that the ordinary mill furnaces used in the manufacture of wrought iron were equally capable of dealing with basic ingots; and, secondly, that rolling mills adapted for working iron plates might, with certain alterations, be used for rolling basic steel also. There was the usual type of shears in operation, and the metal passed through the same treatment afterwards in every respect.

PRESENTATION TO MR. S. G. THOMAS.

Mr. **BÄUMLER** (Kladno, Bohemia) here brought forward a casket, which, he said, the Prager Eisenindustrie Gesellschaft, of which he had the honour to be the director, presented to Mr. Thomas, in acknowledgment of the services which he had rendered to their Society in Bohemia by his patent for the manufacture of phosphoric steel. The casket had been entirely made from metal produced by the basic process, excepting the gold and silver ornaments upon it. The iron ores of Bohemia contained such a quantity of phosphorus, that without the basic process it would have been useless for making steel; but now, thanks to that process, they eliminated the phosphorus and produced perfectly pure metal.

Mr. **GILCHRIST**, in accepting the gift on behalf of his copatentee, said that to all who knew Mr. Thomas it would be a source of sorrow that he was too unwell to be present to thank Herr Bäumler for this most beautiful and gratifying expression of their kind feeling. The present was indeed beautiful, representing skill that he, for one, had never seen equalled It would give Mr. Thomas unbounded pleasure, both for itself and for the very kind feeling that it represented, and the recipient would always rank it as the most precious of his possessions.

In the evening the Annual Dinner of the Institute was held in the Cursalon, Stadt Park. I. Lowthian Bell, Esq., acting President, occupied the Chair, and about 170 sat down. A number of appropriate toasts were proposed and responded to, including "The Queen," "The Emperor of Austria," "The Houses of Parliament," "The Iron and Steel Institute," "The Local Committee," &c.

WEDNESDAY, SEPTEMBER 20TH.

The proceedings of the Institute were resumed this morning in the Hall of the Austrian Society of Engineers and Architects. I. LOWTHIAN BELL, Esq., F.R.S., D.C.L., again occupied the chair.

The first paper read was :—

ON THE ROYAL PRUSSIAN INSTITUTES FOR TESTING IRON AND STEEL AT BERLIN.

BY GEH. BERGRATH DR. H. WEDDING, BERLIN.

THE controversies between the claims of producers and consumers of manufactured products are in no case more severe than in that of the materials of construction, even should there be no doubt as to the existence of the best and most honest purpose on both sides.

The producer will always choose the cheapest and best mode of manufacturing in order to get a material which answers the purpose of its application, whilst the consumer, who mostly bears a considerable responsibility for the safety of the public, is indifferent to the method of production, and only cares that the quality of the material be equal to all possible requirements, even under the most unexpected conditions.

It has therefore always been necessary to make a compromise between the two parties, which enables the producer to employ rational processes and gives to the consumer a full warrant for all probable requirements. On the basis of such a compromise all conditions concerning the delivery of materials for purposes of construction are founded, and on the same principles prices are also calculated and arranged.

It would be easy to ascertain whether the conditions which are thus imposed are fulfilled if every single piece could be tested for its purpose. If, for example, a tyre were not accepted until it had run over 75,000 kilom., nor a rail until it had been used for ten years, nor bridge iron before it had been in use for thirty years, nor an armour plate until the enemy had bombarded it without success, nor a brick until the whole weight of a house had rested on it. It would only be necessary in all these cases to agree on the mode of payment. But because any system of this kind is impossible, and in no case more than for materials of construction, a different method of examination must be sought for.

If a tyre gives way, or a rail breaks, or a bridge girder tears, or an armour plate is shot to pieces, or a brick wall crumbles, damage is done which cannot be compensated by payment or repair, because hundreds of lives may be lost at the same time.

Hence it is absolutely necessary to find a means of ascertaining the quality of a large quantity of articles or materials by the test of a single piece, or even only parts of single pieces, provided that the method of production was the same for the whole bulk.

It is clear that those tests mostly are only intended to prove that the mechanical qualities of materials of construction respond to the requirements which are imposed upon them in practical use; for it is rare in practice, as, for example, with tanks for acid water, that the chemical quality is considered. It is, however, of the greatest interest to the producer, who makes the material by chemical processes, to know how far the chemical constitution influences its mechanical properties, and whether he may be certain that if a piece of a certain chemical composition answers the test imposed by the consumer, all others of the same chemical composition will do the same.

These circumstances furnish the reason why, during the last ten years, Institutes have been established which examine all such questions and give final decisions in cases of doubt or difficulty. It is clear that such Institutes can only be properly controlled by Government, for then only is there a guarantee of entire impartiality and disinterestedness, and an assurance that in each test the interests of the producing and the consuming parties are equally regarded. There also can be no doubt that it is right to make a certain, if only a very small, part of the general taxes of the people pay for the expense of tests which are undertaken for the general welfare.

As I myself, more than ten years ago, influenced by the excellent investigations of Mr. Wöhler, gave the first impulse to the erection of State Institutes for testing materials, I may state, that at the outset I found a very unfavourable field to work in. At that time, it will be remembered, there reigned with us in

Germany the principle of the abstention of Government from any interference with the iron and steel industries, then enjoying the full flood of prosperity. These, then, could dictate the conditions of contracts, and affected to see in the proposed examination of materials an encroachment on their rights.

Now-a-days these relations are quite changed. The system of protective duties, meanwhile introduced, has in itself the character of a State aid; the increasingly depressed state of trade obliged the producers to come to terms with the consumers; but the greater understanding of the latter as regards processes of manufacture made them use their powers within proper limits, and the consequence has been a gradual compromise. This was essentially promoted by the transference of railways to the hands of the Government, by the introduction of the manufacture of armour plates into the country, and by similar changes which have finally brought about an acknowledgment of the necessity for accurate experiments by State Institutes.

The elements of such Institutes, so far as they already existed, were then organised, and their constitution was laid down by the rules of the 23d January 1880.

At the present time, three departments are in existence, two of them being occupied with mechanical, and one with chemical tests.

The Institute for mechanical tests has the duty of examining the strength of iron and other metals, timber, &c.; the Institute for the testing of building materials has the same duty in regard to bricks, cement, lime, &c.; while the Chemical Institute undertakes experiments and analyses in both directions.

The several departments are managed by directors,* who are superintended by a commission under the presidency of the Under Secretary of State for trade and commerce,† viz., the head of the department devoted to the proper development of all branches of industry. Two technical members of the Ministry of Public Works, the one from the department of mines, smelting-works, and saltworks,‡ and the other from the department of railways and architecture,* represent producers and consumers respectively; the third member is deputed by the Ministry of Culture † to guard the interests of technical education.

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* Chemical Institute, Professor Dr. Finkener; building materials, Dr. Böhme; Mechanical Institute, the same, formerly Professor Spangenberg, now deceased.

† Under Secretary of State, Dr. v. Möller.

‡ The author.

The superintendents have full freedom in the carrying out of the experiments, while the Commission preserves the harmony of the three Institutes, and gives impulse and direction to them all.

It may be well not to forget here, that the well-known Association for the Development of Industry ‡ has essentially supported the Commission by indicating the proper direction of the work to be undertaken.

Regarding the work of the Institutes, two groups may be distinguished, the first of which embraces the tests ordered by the State authorities or by private individuals. These are made on payment, and to a great extent cover the cost of carrying on the Institutes.

Work of this character cannot be dispensed with. It seems at the first blush to benefit only the individual person ordering it, and it might appear to some as if this labour would be better done by private enterprise; but by and by a system is built up out of the thousands of results obtained which is of the greatest value in solving problems of general interest, and which can be arrived at in no other way.

The second group embraces the examination of whole series of assays for the purpose of solving the question how the quality of the whole bulk can be ascertained with sufficient certainty from the examination of a small part of a material.

It embraces, therefore, experiments which are not connected with single cases of ordinary practice. The results here obtained fill up the voids which inevitably remain in the results of the first group and give the scientific connection between the methods of production and the quality shown in use,—a connection which really is the great end and aim of the Institute.

In the prosecution of these series of experiments consists the most important work of the Commission.

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* Geheimer Ober-Baurath Schwedler.

† Geheimer Ober-Regierungsrath Dr. Wehrenfennig.

‡ Verein zur Beförderung des Gewerbfleisses in Preussen.

In the last-mentioned direction the work done can be ranged under the following four divisions:—

1. What must be the condition of the sample to allow of a true conclusion as to the nature of the material from which it is taken?

2. In what manner must the sample be tested in order to give a result which is, under given circumstances, always certain?

3. In what connection does the chemical constitution stand to the mechanical qualities, and what is the relation of the different mechanical qualities to each other?

4. What deviations from the chemical and mechanical properties of standard materials are found in pieces which in practice have not met the demands of the consumer?

1. *Condition of Samples.*

The delivery of correct samples is the first condition to permit of true conclusions from the results of the tests. The acknowledgment of this principle has led to detailed specifications, which will be found in an Appendix.

As regards the samples for chemical examination particularly, care in selecting them stands in the first place, and therefore the delivery of larger pieces is demanded, as well as of average samples of borings, so that the latter may be checked as far as possible.

The judicious preparation of samples from such materials, the mechanical qualities of which can be judged of only by their chemical composition, is of the greatest importance. Armour plates, for example, often show a difference of chemical composition in the second decimal, accompanied by an essential difference in their resistance to the action of projectiles.

It is clear that the smallest remainder of gunpowder in a shot-hole whence a sample is taken will make an essential difference in the content of carbon, not to speak of the smallest particle of other organic matters.

The surest way is always to take the sample, if it cannot be done in the Institute itself, under the survey of an officer of the Institute.

In quite another direction the selection of samples for the testing of tensile strength, &c., is difficult.

It is true that under equal circumstances the dimension of the cross section of a sample has only a small influence on the tensile strength, the contraction, and the elongation; but the great difficulty lies in the creation of such equal circumstances. The ingot iron or steel, which is at present mostly used for purposes of construction, frequently shows cavities which interfere with the homogeneity of the material, and the same material, if produced with the addition of spiegeleisen or ferromanganese, and not very carefully mixed, shows even greater want of homogeneity than welded or puddled iron.

The producers of railway material have, with good right, opposed stipulations which are founded on a system of sampling, the very foundation of which seems so uncertain that two pieces of iron taken from the immediate neighbourhood of each other in the same bar give quite different results.

It may be remarked that in this direction the transition of the Prussian railways from private control to the hands of the Government has produced a favourable influence, the great majority of railway managers having agreed on uniform conditions in specifying for the delivery of railway material.

Notwithstanding this agreement, however, there are still many differences to reconcile in the dimensions of the specimens adopted for the purposes of tests, and the Royal Commission for the control of the Institutes, therefore, have carefully considered the best forms of specimens suitable for testing, and have arrived, with the aid of a commission of experts appointed by the German Railway Association,* at specifications which are now examined by the Royal Railway Board, in pursuance of an order of the Minister of Public Works. The dimensions specified will be found in the table attached hereto.†

It is hardly necessary to observe that the manner in which the iron of which a sample is taken has been worked is also a matter of vital importance, as the beautiful experiments of Mr. Brauns of Dortmund conclusively show. These experiments prove that a smaller contraction results from a more thorough working of the iron, so that two pieces of iron alike in chemical composition may give quite different results on being tested with reference to their tenacity. The experience gained on this subject ought shortly to have an important influence on the work of the Institute dealing with the mechanical tests.

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* Verein für Eisenbahnkunde zu Berlin.

† The author showed samples representing the dimensions now generally accepted.

With regard to the samples of building materials in compact pieces, the perfect parallelism of the surfaces on which the compressing strain is to be exerted is the principal condition demanded, and if they are not so delivered, grinding with diamonds in the Institute itself is resorted to. The necessary grinding of borings, &c., to certain sizes is easily provided for in the Institute.

2. *Methods of Testing.*

In all cases and in all the Institutes the modes of testing the samples are such that definite results are obtained as far as possible. The methods of analysis are therefore controlled continually in the Chemical Institute, and these, as well as the apparatus employed, are corrected and improved as occasion arises. The sources of errors, as well as their possible extent, have been determined accurately.

The determinations of certain single elements, such as carbon, phosphorus, sulphur, &c., have been improved in different directions, and the superintendent of the Institute, Professor Dr. Finkener, has, with indefatigable zeal, found out the smallest sources of error.

The cost of apparatus and of reagents is here of less importance than the necessity to seek for methods which enable determinations to be made with sufficient quickness to keep abreast of the requirements of practice.

As regards mechanical testing, the first consideration is that the machinery which is used for the determination of tensile strength, contraction, and elongation be in itself sufficiently accurate to exclude any liability to error, and particularly that the experiments are made under equal conditions. With these objects the machines employed (those of Worder and Wedding) are continually being improved and perfected.

To make sure that the bars which are to be tested are accurately held in position, Dr. Böhme has introduced couplings with spherical surfaces, by the use of which the strain must take the direction of the axis of the bar. (Models and drawings of them are shown.*) The weight is applied equally, and the time of the trial is regulated. Apparatus designed to furnish self-registered diagrams are in course of construction, after the system of Professor Tetmajer of Zurich.

In the testing of building materials, the method of examining cements has been brought by Dr. Böhme to a high degree of exactitude, as a specimen of the moulds employed will show, so that different samples can be compared with certainty, and it is thus easy for the consumer to give well-defined specifications to the producer, and to ascertain whether a particular cement suffices for his requirements.

3. *Connection between the Chemical and Mechanical Qualities, and the Relations of the latter.*

If the solution of the two first-named questions is on the whole empirical, the solution of the third question is based on more theoretical speculations.

It is, for instance, prescribed that an armour plate shall have a certain amount of carbon, not more than a certain amount of phosphorus, &c., but the practical requirement is its power of resisting the penetration of projectiles. It is prescribed that a rail metal shall show a certain measure of contraction or of elongation, but the goal of the producer is to supply a rail which will bear ten years of constant use without breaking or bending or excessive wear.

These are seemingly quite different requirements, but numerous and careful examinations have demonstrated with certainty that a certain connection between them does exist, upon which conditions for delivery can be based and a method of manufacture can be found, which makes it possible, from the ascertained quality of small samples, to draw a conclusion as to the quality of the bulk.

We are, however, far from certain as to a final conclusion. The question, for instance, whether it be better to specify, in addition to a certain tensile strength, the contraction or the elongation, or, in the latter case, if it be not more just to take as measure only a part of the elongation, can be answered at the hand of theory only after a large series of careful experiments; and an even more extended series of experiments is demanded by the problem of the connection between chemical constitution and tensile strength, contraction, and elongation.

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* See diagram.

In this direction the Institutes follow several methods:—First from all bars, &c., which show strikingly abnormal mechanical qualities, samples are taken and preserved for analysis; next, examinations are made on the influence of single elements when the composition of the material is otherwise the same.

I may assume that you are aware of the experiments on the influence of manganese upon iron, made in consequence of the action of the Association for the Development of Industrial Progress in Germany.

Finally, and this brings us to the fourth class of researches, experiments are made on

4. *Deviations from the Qualities demanded in Practice*,

in both a chemical and a mechanical direction; as, for example, experiments on materials which have not met all the requirements of practice, and have been broken, crushed, &c. In this field the Prussian Minister of Public Works deserves a great amount of credit, inasmuch as he has ordered that all the departments of the Government for the supervision of buildings, railways, mines, smelting and salt works, shall send to the Institutes samples of materials which have failed in service, particularly if fatal accidents have been caused thereby; and also that, in all cases where doubts arise as to the suitability of certain materials for constructive purposes, the Institutes shall act as arbitrators between the producers and the consumers.

In this manner we hope it will be possible to bring to a happy solution important questions which are of great moment to the health and life of thousands, and, finally, to prevent all those terrible disasters, the causes of which too often, after a short interval, cannot be investigated at all.

It is not necessary to mention that the duties enumerated do not quite exhaust the work of the Royal Institutes in every direction. You may know, for instance, that at the present time a series of investigations is in progress on the welding of iron, which is nearing a conclusion; while another series is being carried on to determine the conditions of the rusting of iron. It is, besides, very likely that other Institutes will be affiliated to those now existing, in order to experiment, for example, on the construction of prime movers and other subjects of mechanical technology, and on the qualities of lubricants, &c.

Above all things, it is necessary that the Institutes should be protected from being used for advertising purposes. The certificates which are given show, therefore, only the results which are obtained with the sample examined, and no expression of opinion as to its quality or applicability is added. This must be formed by the public by a comparison of numerous results without the aid of the superintendents or the commissioners.

The constitution of the several Institutes will be evident from the particulars given in the Appendix, which also gives the number of orders received and of experiments carried out, including as far as possible those made during the time when the Institutes were not yet under the control of the Government.

You will perhaps be disposed to speak of the work done as small, but you ought not to forget that the Institutes are young, and that they work in fields which only a few years ago were quite undeveloped, and partly even a complete *terra incognita.*

In closing my paper, and referring you for details to the Appendix, I have only now to thank you, Mr. President, for the honour which you have done me, or rather through me the Prussian Government, by desiring me to write this paper, and admitting it into your programme.

I could wish that the result might be the formation of an International Commission of experts of all iron-producing nations, who should agree upon the conditions which should everywhere be employed in testing materials of construction; and I should be happy if you, Mr. President, would adopt that idea as a proposal emanating from the Iron and Steel Institute.

APPENDIX.

A.—THE ROYAL INSTITUTE FOR THE EXAMINATION OF BUILDING MATERIALS (*under the Management of Dr. Böhme*),

Is provided with all the apparatus necessary for examining the resistance and other physical properties of stones, burnt and unburnt bricks, cements, limes, gypsum, also earthenware pipes, roofing felts, and other building materials.

These examinations can be classified as follows :—

I. Testing of stones * and bricks † in general—
  (*a.*) for resistance against crushing;
  (*b.*) their power of absorbing water;
  (*c.*) their power of absorbing water, in connection with cohesive properties, and behaviour against atmospheric agencies;
  (*d.*) specific weight and hardness;
  (*e.*) resistance to cross-breaking;
  (*f.*) behaviour on exposure to high temperatures;
  (*g.*) resistance to tearing.

These tests are applied to stones ‡ and artificial building materials.
  (*h.*) Testing of earthenware pipes by internal pressure, and for their resistance against breakage;
  (*i.*) of roofing felt for its tensile strength and capability of being stretched.

II. The examination of cements § comprises :—
  1. The specific weight of the cement.
  2. The specific weight of the standard sand used in preparing different mixtures (both per litre, after thorough shaking).

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* Eight to ten experiments for each kind of stone.

† Ten to twenty experiments each for bricks and other artificial stones.

‡ Five to ten experiments.

§ In testing the general properties, three experiments each. In testing for resistance against tearing, ten experiments each for the several mixtures, to which different periods had been allowed for hardening.

3. The percentage of water which is needed in the preparation of a mortar of a sirupy consistency.
4. The rise of temperature in mixing water and cement, both of atmospheric temperature.
5. The time required for the hardening of the pure cement, with observations on the temperature of the atmosphere and of the water, and the atmospheric moisture.
6. The size of the grain.
7. The change of volume in setting.
8. The resistance, after hardening, of pure cement, as well as of different mortars made by mixing 1, 2, 3, 4, &c., parts by weight of standard sand with 1 part of cement—
    (*a.*) against tearing;
    (*b.*) against crushing;
    (*c.*) against breaking across;
    (*d.*) testing the adhesive power.

Sets of specimens are prepared, to which 7, 28, 90, &c., days are allowed for hardening—

(*a*) in the air only;
(*b*) during the first days in the air, and subsequently under water.

According to the law of the 12th November 1878, which lays down uniform rules for the supply and examination of Portland cement, these tests are extended—

(*a.*) to the general properties, as under 1–7;
(*b.*) to the resistance against tearing [after hardening for seven and twenty-eight days respectively], of a mortar which contains three parts of sand to one of cement, accompanied, as a rule, by an application of the same test to pure cement, the same time being allowed for hardening.

III. Examination of lime and lime mortar, analogous to the cement tests.

IV. Examination of trass-mortar.

V. Examination of tripolith.

VI. Comparative examinations of mortars made with granulated or ground slag, and with standard sand respectively. These last three materials are tested in accordance with the rules laid down for the testing of cements.

VII. Examinations of timber for rot (*Merulius lacrymans*).

Within a period of eleven years, from the opening of the Institute on the 1st March 1871 to the 1st April 1882, these rules have been adhered to. During this time 1828 orders have been executed by 46,584 experiments, viz., in the working year

1871–2	= 29	orders by	665	experiments.
1872–3	= 27	"	318	"
1873–4	= 53	"	362	"
1874–5	= 177	"	5,975	"
1875–6	= 91	"	3,642	"
1876–7	= 97	"	1,944	"
1877–8	= 134	"	2,974	"
1878–9	= 153	"	3,963	"
1879–80	= 281	"	6,015	"
1880–1	= 214	"	6,469	"
1881–2	= 572	"	14,257	"
Total,	1828	"	46,584	"

1608 of these orders, representing 18,391 experiments, demanded examinations as specified under I. *a–i.* The specimens operated on were received in a state of preparation as prescribed in the rules laid down by a committee of experts. The other 222 orders, representing 28,193 experiments, referred to building materials, as specified under II.–VII., viz., cement, lime, trass, tripolith, and disintegrated slag, and included the mixture and preparation of the test specimens.

In examining specimens as under I. by pressure, particular attention is paid to *a* throughout even support of the test-pieces; ball-sockets are made use of with this object. Specimens not properly prepared are either rejected or are finished before testing, in accordance with the general rules referred to above.

Natural stones are tested by pressure in three different forms, viz.—

1. In the form of plates of 10 × 10 × 5 ctm. (3·93 × 3·93 × 1·96 in.), the pressure acting perpendicularly to the 100 sq. ctm. (15·44 sq. in.) section.
2. In the form of cubes of 6 × 6 × 6 ctm. (2·36 × 2·36 × 2·36 in.), the pressure acting on a section of 36 sq. ctm. (5·57 sq. in.)
3. In the form of prisms of 10 × 10 × 40 ctm. (3·93 × 3·93 × 15·72 in.) and 10 × 10 × 60 ctm. (3·93 × 3·93 × 23·58 in.), the pressure acting on a section of 100 sq. ctm. (15·44 sq. in.)

In experimenting with very thin plates of about 2–3 millim. (·08 to ·12 in.) thickness, and of different sizes, no satisfactory results could be obtained. In consequence of the minute height of the specimens, free play is not given to the tendency to form the well-known truncated cones and pyramids. The plate, however nicely prepared, will break into several fragments, each of which is individually intact, and will, on being subjected to a fresh trial, show a resistance nearly equal to, in many cases even greater than, the original plate.

Systematic trials of a general character have been executed on resistance against crushing. (*A.*) With test-pieces of a constant thickness of 6 centim. (2·36 in.) and of different sections, viz., 200, 150, 100, and 50 square centim. For each thickness five different test bodies were employed, viz., one of circular, one of quadratic, and three of rectangular sections, the sides of the latter having the proportions of 1 : 2, 1 : 3, and 1 : 4 respectively. (*B.*) With test-pieces of constant sections of 200, 150, 100, and 50 sq. centim. respectively, and thicknesses graduated by differences of 1 centim. In the case of the circular and quadratic sections, these grades were extended up to heights equal to the diameter of the circular ($h = d$) and the side of the quadratic sections ($h = a$).

One of the many interesting results of this investigation was the conclusion arrived at that the true resistance against crushing should be determined, for cylinders with $h = d$ and for quadratic prisms with $h = a$ (viz., with a cubical body). To the values so obtained particular importance should be given, as with the same thickness the resistance per square millim. against crushing increases as the section increases, and with the same section the resistance decreases as the height increases.

In testing stones, cubical specimens only, of the convenient medium size of 6 × 6 × 6 centim. are admitted, the preparation of cylindrical bodies with $d = h$ being too expensive. However, the resistance of such cylindrical bodies exceeds that of the cubes,—a fact explained by the more favourable arrangement in cylinders of the particles of the mass in relation to the axis of symmetry, as compared with bodies of a quadratic section.

An opinion having established itself of late years, that for stones the resistance against crushing be proportional to their specific gravity, an investigation was undertaken to inquire into this question. This series of experiments was very complete, and comprised for each variety of stone eight experiments with cubical specimens, one set of them being dry, the other saturated with water. After arranging the data obtained in the order of the specific gravities of the specimens, it was proved that the above-mentioned opinion is not tenable.

The tests for artificial and natural stones, in the dry and wet state, are repeated at least ten times for different arrangements of the trial. The following combination of tests, in accordance with the general scale under I. *a*—*e*, has now for a number of years been successfully applied to stones and bricks:—

1. Resistance against crushing of the air-dried stone—10 experiments for each specimen.

2. Absorptive power for water (10 experiments), cohesive property, specific gravity, hardness, resistance against atmospheric agencies; together, 10 experiments.

3. Resistance against crushing of the material when saturated with water.

4. For bricks, in most cases, the resistance to cross-breaking in the air-dried condition, in consideration of the projections frequently occurring in building practice.

Examinations of the behaviour on exposure to high temperatures, as under I. *f*, have so far only been made in a limited number. In compliance with the requirements of the several orders, this question had to be considered only in regard to the probable behaviour of the materials in case of fires.

For the purpose of these trials twenty test stones or bricks are employed; ten of these are weighed as received, then dried for twenty-five hours in a moderately warm place, and subsequently—

1. Gradually warmed by one hour's exposure in the oven of an air-heating apparatus.

2. Heated for three hours in a good peat fire.

3. Heated for four hours in a sharp coke fire, up to a white heat.

4. Exposed for four to eight hours to a coal fire on the fire-bridge of the furnace.

5. Gradually allowed to cool in the furnace.

6. Weighed, and then tested for their resistance against crushing, to which latter test the ten specimens which were not fired are also submitted. The comparison of the two sets of results will show the influence of the firing.

The resistance against tearing, as under I. *g*, is frequently tried in the case of stones. The test-pieces are shaped to the well-known pattern of the cement test-pieces.

Earthenware pipes are tested, as under I. *h*, by internal pressure, after carefully grinding their heads; also, in order to test the jointing, after cementing two of them together.

Single pipes are also tested for their resistance to cross-breaking, in order to obtain information on their probable behaviour if insufficiently packed in laying down.

As far as possible, pipes are tested in sets of three or four various diameters, which, in consideration of the testing machine at present available, have to be of not less than 120, and not more than 350 millim. internal diameter.

Five pressure experiments are made for each size, and five pipes of medium size are tried for resistance against cross-breaking. Ten to twenty of the fragments of each set of pipes, each of 1 to 2 kilos. weight, are tested for their absorptive power for water, their cohesive properties, specific gravity, hardness of the original and of the ground surface, and resistance against atmospheric action. These investigations have supplied a very interesting and valuable material.

The examination of asphalted and other roofing felts, referred to under I. *i*, for tensile strength and capability of being stretched, is conducted in the following manner:—Four specimens are cut into straps of 15 centims. width and 60 centims. length, taking care to select them of the average thickness of the manufacture represented. These serve to test the tensile strength; the load is gradually increased till rupture takes place, when the longitudinal extension of the specimens, the contraction of their sections, and the distance of the point of rupture from the fastenings is ascertained.

Four other specimens of the same dimensions are tested only for their capability of being stretched; for this purpose they are submitted to a strain which increases much more slowly than in the tests for tensile strength, and which is raised up to 50 to 75 per cent. of the tensile strength.

In reporting on the results of these experiments, careful attention has to be paid to the thickness of the test-pieces, particularly when different makes are to be compared. The thickness must agree exactly with that of the regular make of the different works as they supply it for ordinary use, otherwise a fair comparison cannot be arrived at. Samples made of extra thickness for the purpose of the tests ought to be rejected, as they lead to uncertain and deceptive results.

The tests used in the examination of cements have been detailed above. It only remains to be added that the greatest care is needed in the preparation of the test bodies which are submitted to the trials.

The quantity of water which the pure cement requires to form a mortar of syrupy consistency is first ascertained, and serves as a guide in the preparation of the test-pieces. If Q is the percentage of this water, $(Q-3)$ per cent. of water are used in the tests for hardening, change of volume, and resistance against tearing.

The quantity Q for German cements varies from 29 to 42 per cent.

Pure cement for the purpose of these trials is best treated so that after being properly mixed with water it is poured into the moulds, while these are shaken to remove all air bubbles. It will then settle in accordance with its nature, and yield exceedingly sound casts.

The box (a model of which is shown) is constructed for the preparation in one cast of five specimens from pure cement. The casts can be made quickly and very exactly, and the differences in their respective weights do not amount to more than 1 or 2 grammes.

In the preparation of cement mortars, the mixtures are made of about the stiffness of moulding sand, so that they can be moulded in the hand. Accordingly, the average requirement of water for a mortar of

				Per cent.
1	part by weight of cement and	1	part of standard sand, is	14–15
1	„ „ „	2	„ „ „	11–12
1	„ „ „	3	„ „ „	10
1	„ „ „	4	„ „ „	9
1	„ „ „	6	„ „ „	8

In this case, the test bodies are prepared by throwing the mass into a mould, placed on a metal plate, and beating it till it becomes of an elastic consistency and water appears on the upper surface.

In the subsequent cutting down and smoothing with a knife care has to be taken lest particles of mortar are torn out from the contracted place intended for the tearing of the specimen.

In reporting on the quality of cements and cement mortars, mention has to be made of the nature of the base—absorptive or non-absorptive—on which the test-piece has been prepared.

Examinations of cement in most cases are conducted in accordance with the standard rules laid down by the Royal Prussian Ministry in the law of November 10, 1878. These have been repeatedly published, and have proved very satisfactory.

As mentioned above, other varieties of mortars are in the main examined in analogy with the tests of cement mortars; it only remains to be added, that in the case of lime mortars and lime-trass mortars, it has been found of advantage, for experimental purposes, to work up the lime if possible in the form of the dry hydrate. A more thorough mixture of the several ingredients is more easily obtained, consequently the influence of individuality in the usual way of making up mortar is to a great extent excluded—a circumstance of great value where uniform treatment has so carefully to be aimed at.

The working up of the lime in the form of a paste is undoubtedly not conducive to the accomplishment of this object, and is an obstacle to the attainment of uniform results in trials performed at different places.

The trial of the adhesive power of mortars is considered to be of great importance. After properly jointing two bricks crossways they are torn asunder; and this test, provided the joint is made in a workmanlike fashion, is a very good criterion of the adhesive property of the mortar, not only by the actual figures so obtained, but also by an examination of the surfaces of the fractured joint.

It is to be recommended that this test be made with at least two varieties of bricks, for which, with advantage, hard-baked bricks (Blinkers) and moderately-baked bricks (Rathenow bricks) may be selected.*

B.—The Royal Mechanical and Technical Testing Institution
(*under the management of Dr. Böhme*).

This Institution comprises two departments.

1. The older department, which has been in operation since 1872, with the object of carrying on long-continued and frequently-repeated trials (time trials) with metals.

2. The Institution for the testing of and experimenting with materials, which was opened in 1879.

Both departments were under the management of the late Professor

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* The following are some of the publications dealing with the work of the Royal Institute for the testing of building materials:—

1. Die Festigkeit der Baumaterialien (The Strength of Building Materials). Nicolaische Buchhandlung in Berlin.
2. Betriebsbericht pro 1877 (Report for 1877).
3. Betriebsbericht pro 1878 (Report for 1878).
4. Paper on the results obtained with twelve German cements tested according to the Prussian rules, in comparison with results obtained in testing the same by the Russian rules, published in the report of the general meeting of the Society of German Cement Manufacturers.
5. More detailed treatment of the same subject (4), printed for the above Society, in the "Verhandlungen des Vereines für Gewerbfleiss" of 1878 and 1880 respectively.

The report of the work of the Institution in 1879, 1880, 1881, will probably be published in the spring of 1883.

Spangenberg up to his death on the 6th August 1881, when they were provisionally transferred to Dr. Böhme.

The work of the first department is directed towards proving, by repeated and further continued experiments, the general validity of the maxim laid down by Wöhler that "The fracture of a material may be effected by frequently repeated *impact*, which in no case equals the absolute breaking strain."

The second department, viz., the mechanical and technical testing office proper, has the task of carrying out experiments of a general, scientific, and public interest, and to execute orders emanating from the Government authorities or from private people, on the elasticity and resistance of materials.

I. In the laboratories for the carrying out of the continued experiments there are ten machines, almost uninterruptedly in motion, as constructed and used formerly by Wöhler; they are devised for the production of tensile, bending, and twisting strains. The machines at present in use are—

1. Two machines in which eight metal rods, each of 9 millim. diameter and 60 millim. length, can simultaneously be submitted to repeated tensile strains.

A direct-acting maximum load of 60 kilos. can be applied by means of spring dynamometers; but through tenfold and fivefold lever transmissions, an indirect load of 3000 kilos. can be applied.

2. Three machines which can receive nineteen prismatic bars of 800, respectively 1700 millim. working length, of a maximum sectional modulus of $\frac{b\,h^2}{b} = 3000$ (on the millimetric scale); these machines serve for the repetition of one-sided bending strains, up to the breaking of the test bars, the load, as in the machine under 1, being measured by spring dynamometers.

3. Two machines which can each receive six bars of a diameter of 26 millim. and a free length of 400 millim.; these bars are fixed at one end, while the other is bent out and kept in a continuous rotary motion round the original axis of the bar: an ever-changing extension and compression of the fibres is so produced. A load up to 120 kilos. can be applied by means of ∞ springs.

4. Three machines for the exertion of continuously repeated torsional strains simultaneously on three test bars of 20 millim. average diameter, and 210 millims. working length, with a sectional modulus (on the millimetric scale) of $2000 = \frac{Tl\,d^3}{32}$.

The load acting on the end of a lever of 310 millim. length by a spiral spring dynamometer can be raised to 60 kilos.

These ten machines are actuated by a gas-engine of two-horse power; in the case of those under I., II., and IV. by eccentric and lever transmission; in the case of III. through pulleys and belts.

The number of the strains to which the test bars have in the course of each experiment been submitted is recorded, in the case of the machines, under I., II., and IV., by means of indicators attached to the transmitting gear. For the machines under III., additional provision is made to have the number of strains for each one of the twelve test bars recorded by separate indicators.

Material.	Number of Experiments.	Load per Square Millim.	
		Maximum.	Minimum.
I. *Tensile Strain.*			
Wrought iron	19	35	20
Steel	22	47	33
Bronze	15	18	7
Total	56		
II. *Bending in one direction.*			
Pig iron	13	8	4
Wrought iron	15	40	26
Steel	31	12	33
Bronze	8	15	11
Copper	1	...	11
Total	68		
III. *Bending in changing directions.*			
Wrought iron	19	25	16
Steel	12	29	22
Bronze	4	7	6
Wire ropes	22	...	...
Total	57		
IV. *Twisting.*			
Wrought iron	6	18	7
Steel	11	21	13
Bronze	9	22	20
Wire ropes	1	...	...
Total	27		

Total number of all experiments, 56 × 68 × 57 × 27 = 208.

The daily working time in this Institution has so far been fixed to twelve hours, excluding Sundays and holidays. In the ten years during which it has been in operation, 208 test bars of pig iron, wrought iron, steel, bronze, and wire rope have been fractured.

The maximum and minimum strains to which the materials were subjected were 47 and 4 kilos. per square millim. They are given in the foregoing table.

In consideration of the important bearing of Wöhler's experiments, a new and comprehensive programme for the continuation of the same has been worked out.

This programme provides, above all, that the interruptions of the working, hitherto occasioned by the twelve hours' rest during the night, and by Sundays and holidays, be avoided, because they must in a measure allow a recovery of the molecular condition from the effects of the work done previously. This must lead to deceptive conclusions, so much the more as the increase in tension varies very much for different strains and different materials.

It is furthermore intended that the whole of the specimens of material belonging to one set of tests be of a uniform composition, to be proved by chemical analysis, and be produced by the same metallurgical and mechanical processes.

In order that all shocks by hammering, &c., in the shaping of the test bars shall be avoided, they are to be cut out of larger pieces, and to be finished with clean and smooth surfaces in the lathe and planing machine.

The influences of notable changes in the atmospheric temperature and moisture are to be excluded as much as possible, so that any modification by these agencies of the physical properties of the metals under trial be eliminated.

In consideration of the imperfect homogeneity of all materials, it is intended not to employ less than five test bars for the same trial, in order to arrive at a reliable average result.

Each series of experiments will require thirty test bars, properly finished in perfectly identical dimensions. Five of these, before arranging for the time trials, are to be tested by Werder's machine for their tenacity, ductility, and elastic properties, and the limit of proportionality, the beginning of permanent deformation, the changes during deformation, and the degree of bending or twisting up to the moment of rupture, and after rupture have to be carefully observed and recorded.

From the data so obtained respecting the general behaviour of the material, the decreasing scale of the loads to be applied in the time trials will be calculated; the rate at which the loads decrease must be a very gradual one.

Next the molecular changes produced in the time trials will have to be investigated. In order to form an idea of the progress of the same, five of the bars which are exposed to moderate strains only are set apart for the purpose of being kept under the strains for a certain period (campaign) only, and then to be tested in Werder's machine in exactly the same manner as the five original specimens referred to above. Subsequently, at the end of a second and third campaign, a second and third set of five each of the test bars will be withdrawn from further treatment, and tested for elasticity and tenacity like the two former sets, so that the progress of the gradual deterioration by these continued strains will be clearly traced.

Altogether five campaigns or periods of exposure are recommended for each set of test bars, the last set to be kept under treatment till rupture takes place. Sections from the several specimens which have served for the tests in Werder's machine, as well as of the bars ruptured at the end of the time trial, are to be polished for microscopic examination, in order to see whether any changes of structure may be made sufficiently visible to arrive at conclusions useful for practical purposes.

It is also intended to supplement these time trials with moving machinery by others in which dead loads are used. There are in the Institution at present two machines, also constructed by Wöhler, by which tensile and twisting strains of this kind can be exerted. They only allow, however, to operate on bars of small dimensions.

It being a recognised want, for practical purposes, to have certain details of machinery subjected to time trials, it is proposed in the first instance to operate—

1. On riveted joints and screw couplings, to investigate the influence of vibrations, and particularly of shocks.
2. On belts, ropes, and chains with bending strains, and on their stretching and wear.
3. On journals, bearings, wheel teeth, &c., in order to examine not only the resistance but also the hardness of the material, and the influence on it of wear and friction. Examination of the action of lubricants on such parts in general, and of their quality, can be combined with these trials.
4. On welded joints.

Experiments on Wöhler's system correspond more than any others to the conditions under which materials are employed in practice. The results which at the present time have been obtained, and those to be looked for from their further development, will undoubtedly be of great value in creating a true basis for scientific calculation and safer standards for comparing the quality of materials, particularly metals. The experiments, however, are expensive, and much time is required in carrying them out.

Tests which give immediate results are therefore needed, for there is an undeniable want on the part of commerce and industry, particularly in the interest of the railway and engineering departments, to have the means of examining the value and usefulness of materials in a comparatively short time and with certainty.

II. The Institute for the testing of and otherwise experimenting with materials, viz., the Mechanical and Technical Testing Institute proper, has at its disposal the most important machines of precision and micrometric apparatus which are requisite in all appropriate and exhaustive trials.

At present its laboratories are supplied with—

1. A Werder's machine of precision by which loads up to 10,000 kilos., produced by hydraulic pressure and measured by weights, can be applied. The micrometric apparatus used in experimenting on extension or compression allows to read off accurately within 1–5000 of a millim.

Experiments on bending, twisting, and crushing by bending can be carried out on the same machine; and telescopes, microscopes, and scales are provided by which an equal degree of accuracy in reading off is attainable.

2. A vertical testing machine by W. Wedding, Berlin, the highest power of which is 40,000 kilos. It is provided with a very delicate circular measuring apparatus. This machine allows us to observe the progress of elongation up to the moment of rupture, independently of the test bar.

3. A cathetometer by Breithaupt of Cassel, an instrument of the greatest exactitude.

4. A tube-testing machine, in which tubes up to one metre diameter can be tried by internal pressure.

5. An apparatus for trials of hardness by the drop test.

6. A machine for tearing wires, fibres, and woven goods.

7. A large number of apparatus and instruments for the accurate

measurement, particularly of thickness, of vessels, of plates, and wires; also planimeters, thermometers, hygrometers, manometers, &c.

The outfit of this Institution will be shortly considerably added to and perfected; and on its removal, in autumn 1884, to Charlottenberg, near Berlin, it will have ample accommodation in buildings constructed especially for its purposes.

To the testing appliances of its laboratories will be added machines and apparatus to try railway material by the drop and bending tests; a bending machine for the testing of plates; an apparatus for the testing of wires for their resistance to bending and twisting strains; an arrangement for the application of equally distributed loads, particularly intended for corrugated plates; a self-registering galvanic measuring apparatus, for the longitudinal extension in trials on tensile strength; and a reverberatory furnace, for the testing of heated iron.

A valuable addition to the new laboratories will be a workshop of 120 square metres area. Within the period from 1st April 1879 to 1st July 1882 there have been performed in the laboratories of this Institute 1038 trials, partly in execution of experiments of general scientific and public interest, partly in compliance with orders from public authorities and from private individuals.

A.—TESTS OF MATERIALS.

1. *For Tensile Strength.*

Cast iron	35	trials.
Wrought iron	205	,,
Ferromanganese	32	,,
Steel	146	,,
Bronze	8	,,
Copper	18	,,
Wires	27	,,
Total	471	,,

2. *For Resistance to Crushing.*

Cast iron	11	trials.
Wrought iron	12	,,
Steel	1	,,
Total	24	,,

3. *For Resistance to Cross-breaking.*

Cast iron	25	trials.
Wrought iron	13	,,
Ferromanganese	20	,,
Total	58	,,

4. *For Resistance to Wrenching.*

Wrought iron	6	trials.

B.—TESTS OF DETAILS OF MACHINERY.

1. *For Tensile Strength.*

Fish-plates	65	trials.
Chains and pulleys	11	,,
Saw hinges	2	,,
Flat and round ropes of metal, vegetable fibres, india-rubber, and leather	360	,,
Riveted joints	17	,,
Total	455	,,

2. *For Resistance against Crushing.*

Tubes	2	trials.
Dished plates	3	,,
Corrugated plates	2	,,
Total	7	,,

3. *For Resistance against Cross-breaking.*

Tubes	5	trials.
Wrought-iron I beams	1	,,
Cast-iron shafts	1	,,
Do. journals	2	,,
Galvanised corrugated plates	5	,,
Total	12	,,

4. *For Resistance to Crushing by Bending.*

Tubes	1	trial.
Cast-iron columns	2	,,
Total	3	,,

Sum total, 1038 trials.

Of which 559 were trials of materials, and 479 were trials of details of machinery, &c.

An extensive series of tests of 269 specimens of round and flat ropes, of various nature and construction, which were made at the instance of the Union of Berlin Ropemakers, is worth notice.

Another interesting order emanated from the Society for the Promotion of Industrial Progress, consisting in an investigation on the weldability of twelve varieties of steel and iron in one hundred and sixty-seven trials, and experiments on the strength of riveted joints, and the plates and rivet material of which they were composed, in eighteen trials.

Besides the above-detailed routine work, there have been executed under the present management some scientific investigations on elongation during trials on tensile strength, a great number of show experiments before royal and city authorities, and lectures accompanied by practical trials before the students of the Royal Polytechnic High School.

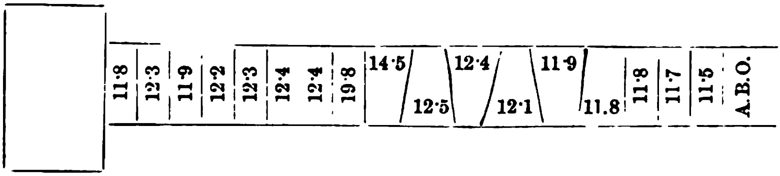
The series of rope tests referred to above was supplemented by a number of similar examinations. In these a new contrivance for the fastening of the specimen under trial, devised by Herr Kortüm, and executed in the Institute, gave very great satisfaction. With its help it has been made possible to apply in the tensile tests the load in a true axial direction, and to work without having to tie the ropes to chains—a method of fastening which frequently will damage the rope in the tie, and so falsify the results. Indispensable for the obtaining of good results is—

1. A perfect finishing of the test bars and of their surfaces.
2. An appropriate and accurately executed fastening of the specimens under trial.

The method of fastening hitherto generally used, in the case of flat bars by means of biting wedges, in the case of round bars by means of conical and globular heads, being productive of vertical tensions, boxes with ball-sockets (drawings of which are shown) were introduced with the most perfect success.

It is intended to conform, as regards the dimension of test bars, with those customary in engineering, and in particular, of railway practice. Except where investigations of a purely scientific nature require special dimensions, the following measurements, accompanied by the use of ball-socket fastenings, have been chosen:—(*a.*) For round bars, a working length between marks of 200 millim. distance, and a diameter of 20 millim., thickening into globular heads of 35 millim. diameter;

(*b.*) for flat bars, ball-sockets for larger dimensions only, thickness equal to that of the material up to 20 millim.; above this they have to be reduced to round bars of 20 millim. diameter, width 40 millim.; prismatic part between marks of 200 millim. distance, thickening towards the heads on each side. Interesting results were obtained in experimenting on irregularity of elongation, as appears from the example shown in the following sketch:—



The original length of each of the different parts was 10 millim. In giving certificates of the results obtained in testing for tensile strength, the percentage of the elongation as far as it results from an original length of 100 millim. is given, in addition to that of each 50 millim. within equal distances from the point of fracture.

3. To some other portion of the trial length of 200 millim. This will be evident from the subjoined forms for the results, for round bars in the 16th, and for flat bars in the 15th column.

Results obtained lately in systematic series of experiments make it appear desirable—

(1.) To ascertain and record the degree of elasticity existing in metallic—particularly steel—bars after rupture.

(2.) To take careful notice of the influence which the method and rate of increasing the load, the shape and size of the section, and the temperature, exerts on the results obtained for tensile resistance and elongation.

Results of the Examination for Tensile Strength, &c., of Round Bars.

1.	2.	3.	4.	5.	6.	7.	8.	.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
Description of bar, and No. of trial.	Description of material, and whence obtained.	Original section.		Distance of marks.	Limit of elasticity. Load.		Modulus of elasticity per sq. millim.	Beginning of stretching. Load.		Breaking strain. Load.		Fractured section.		Average distance of place of fracture from nearest mark.	Elongation referred to a length of		Contraction of section.	Remarks on the appearance of		General remarks.
		Diameter.	Area of section.		Total.	Per sq. millim.		Total.	Per sq. millim.	Total.	Per. sq. millim.	Mean diameter.	Area.		... mm. within distances of ... mm. and ... mm. from place of fracture	100 mm. at distances of 50 mm. each side from place of fracture.		Fracture.	Surface after fracture.	
		mm	sq. mm	mm	kilos.	kilos.	kilos.	kilos.	kilos.	kilos.	kilos.	mm	sq. mm	mm.	per cent.	per cent.	p. ct.			

Results of the Examination for Tensile Strength, &c., of Flat Bars.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Description of bar, and No. of trial.	Description of material, and whence obtained.	Distance of marks.	Original section.			Beginning of stretching. Load.		Breaking strain. Load.		Fractured section.			Mean distance of place of fracture from nearest mark.	Elongation referred to a length of		Contraction of section.	Remarks on the appearance of		General remarks.
			b.	h.	F.			Total.	Per sq. millim.	b.	h.	F.		... mm. of ... mm. and ... mm. distance from the place of fracture.	100 mm. of 50 mm. distance each side from the place of fracture.		Fracture.	Surface after fracture.	
		mm	mm.	mm.	sq. mm.	kilos.	kilos.	kilos.	kilos.	mm	mm	sq. mm	mm.	per cent.	per cent.				

C.—THE ROYAL LABORATORY FOR THE CHEMICAL EXAMINATION OF TECHNOLOGICAL OBJECTS

(*under the management of Professor Dr. Finkner*).

The Royal Laboratory for the chemical examination of iron and other metals and materials is attached to the Royal School of Mines at Berlin, aud therefore superintended by the Mining Department of the Government.

It has been established for the purpose of undertaking experiments of general scientific and public interest, and to execute chemical examinations on the demand of the Government authorities and private persons.

Ever since the chemical laboratory of the Royal School of Mines has been opened, viz., since the year 1863, experiments and analyses have been performed in it which had reference to questions arising in the carrying out of the mining and other industrial undertakings, borings, &c., of the Government. However, the present enlarged sphere of the Institution, connecting it with the other testing Institutions described above, has been given to it by the organisation of 1880.

The Professor of Chemistry at the Royal School of Mines, Dr. Finkner, as the head of it, is assisted by a number of chemists who carry out the investigations according to his special directions. The Institution, though located in its own rooms, is in close connection with the laboratories of the Mining School, so that the whole of the very complete apparatus of the latter is available whenever necessary, and each office may benefit by the experiences and appointments of the other.

The laboratories are fitted with all the appliances necessary in the analysis of inorganic substances and fuels, and in the performing of metallurgical investigations—by calcining, fusions, &c.,—on a small scale. Analyses and assays are carried out by the most trustworthy methods only, and with the greatest possible care; therefore examinations in which only approximate results are required, as in many commercial analyses, are not undertaken.

Samples have to be forwarded to the Institution in a powdered condition, accompanied by a larger specimen to show their nature before disintegration, in case an examination of the physical properties is required likewise, and objects of suitable size and shape have to be sent in.

In preparing drillings, &c., from hard bodies (steel, spiegeleisen,

&c.), care has to be taken that no parts of the instruments used for disintegrating vitiate the sample.

The quantity of substance to be supplied has to be, as a rule, not less than twenty grammes for solids, not less than one litre for liquids, and not less than five litres for gases.

It is necessary that the sender should accurately describe how the sample was obtained, and for what purpose it is to be examined, otherwise it may happen that a complete analysis, entailing much expense and time, is made to no purpose, while if the object of the test had been previously known, the determination of one or a few of the constituents would have given the desired information.

The charge made for analytical and other examinations is calculated in accordance with the time occupied in their execution, and the materials and apparatus used. The cost of the determination of a single body is from five to fifteen marks,* of a complete analysis of iron or coal, about forty marks, of a complete analysis of ores, slags, &c., ten to fifty marks.

It is the rule in examinations for purposes of arbitration to make duplicate analyses; in such cases, therefore, a double charge is made. The analyses and assays—at present about three hundred per annum—are undertaken—

1. On application from the mechanical testing offices, either as part of the original order received by them, or in order to throw light on striking irregularities which may show themselves in the mechanical tests. Some of the more important series of examinations under this head referred to the influence of manganese on the quality of iron; to comparative trials on the weldability of iron, in particular ingot iron; and to a large number of mechanical examinations of cements, in connection with which the chemical nature is a matter of the highest interest to the manufacturers.

2. In order to decide whether certain properties of metals and other materials forwarded by the authorities or by private persons correspond with such conditions as may have been agreed on by contract.

3. With a view to arrive at certain conclusions in respect of the qualities of materials as they manifest themselves in practical use. The tests of armour plates here claim the first consideration.

An idea of the exactitude and care necessary in these analyses can be formed from the fact that differences in the carbon of ·05 per cent. essentially modify the quality of the material. A great part of the analyses hitherto carried out are of this kind. Amongst other investigations of scientific metallurgy, an extensive series of synthetical experiments has been undertaken in elucidation of the behaviour of sulphur in Thomas's dephosphorising process. It is well known that the peculiar fact of the very imperfect elimination of this element in the basic process was first clearly recognised by investigations carried out in the Institute. The causes of this particular feature, first established after analysing several series of consecutive samples in conjunction with the whole of the reactions occurring in the process, have been investigated by synthetical trials, an account of which will shortly appear in print.

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* 1 mark = 1 shilling.

These experiments refer to the action of metallic iron at a white heat on silica, phosphoric acid, phosphate and pyrophosphate of iron, sulphurous acid, and sulphate of lime; to the action of carbonic acid on metallic iron and iron phosphide; of carbonic oxide on iron oxide, iron and iron phosphate, and a mixture of iron phosphate with iron oxide; of hydrogen and iron carbide on iron phosphate.

4. The checking and improvement of analytical methods and the apparatus required forms a considerable item in the work of the Institute. Investigations bearing on this subject are carried on side by side with the other work, while those coming under the third head can be undertaken only when time allows it. Rules have been drawn up, and have been in force since the 1st January 1881, in accordance with which the several Institutions are made available for the public use. The following conditions are to be observed in forwarding samples:—

Procedure in the Sending of Samples.

Proposals for the carrying out of tests, experiments, and analyses of general scientific and technical interest have to be made to the committee of supervision. To the same committee all orders emanating from the Government authorities have to be directed, excepting those which refer to decisions on the quality of cements. These have to be made to the head of the Institute directly, marked "Immediate," as have also all applications made by private persons. The heads of the several departments are bound to give the orders of the public authorities preference to those of private people. The latter have to be taken in hand in the order in which they were received. Exceptions to this rule are only allowable when approved of by the committee of supervision. The heads of the departments conduct the correspondence referring to private orders. Direct correspondence with Government authorities who have given orders through the committee is admissible only in case further explanations are required in reference to the subject under examination.

In case that orders claiming treatment in more than one of the departments have been directed to the head of one of them, the latter has to transfer a suitable part of the sample to the other departments, and no further direct application to the latter is required from the person desiring the examination.

The heads of the several offices are bound to observe the strictest secrecy in respect of all orders, and no communications in conversation or by writing are permitted to be made to third parties on the subject of examinations.

Reports on the examinations made for private persons are given by the heads of the Institutes. They have, however, to be confined to a strictly scientific statement of the results obtained, and it is not allowed that any opinion be given on the usefulness of the article or material in question, or its applicability for certain practical purposes. The directors are not even permitted to give to private persons certificates on any kindred matters (according to pars. 16 and 13 of the Regulations of the 23d January 1880).

It is intended, in the interest of science and practice, to publish annually the results of the work of the several departments. In no case, however, will information on the origin of the several specimens and the names of the persons who supplied them be given, unless with the latter's consent; and, if so desired, no public mention at all will be made of the experiments.

DISCUSSION.

Professor W. **Chandler Roberts** said that in view of the great progress that had been made in conducting mechanical tests, it was difficult to believe how comparatively recent such tests were. Of course, when the early work was done by Knut Styffe, and in our own country by D. Kirkaldy, chemists did not know what important factors one-tenth per cent. of carbon, or even one-hundredth per cent. of phosphorus, could really be; nor had the present era of molecular metallurgy dawned, in which the chemist shared with the physicist the responsibility for success or failure in the manufacture of iron or steel. Dr. Wedding's view, that in England the work need not be assumed by Government, was probably correct. There was great reluctance on the part of Government to undertake such work, and much indisposition on the part of manufacturers to submit to tests conducted by the State. His own view was that the work was better left in England to private enterprise; and he might point to the admirable work now being done by Professor Kennedy as a proof that State control was unnecessary. He might mention that the final tests of the weight and fineness of the British gold coinage, the annual value of which was five millions sterling, were not undertaken by Government, but were left in the hands of a private corporation—the Goldsmiths' Company of London; and he thought that a better illustration of the national tendency to leave work in private hands rather than to put it in those of a public department could hardly be found. They had all listened with great interest to Dr. Wedding's valuable paper, and they rejoiced that the intimate relation between the mechanical properties and chemical composition of steel was now so completely recognised.

Mr. **Snelus** said they must be cautious not to draw conclusions from a small number of samples. He thought they had often failed by drawing conclusions in that way. On the other hand, it was very difficult to ensure that all the samples were taken in the same way. As they had just been told, the difference in the material itself produced results which were far greater than the differences in the mode of preparing the sample. He did not think it was possible to take two pieces of plate steel, even of the finest quality, and get absolutely identical results in the testing machine. Then, again, he wished to point out that they wanted to connect the chemical composition with the mechanical test; and he thought that was the point where Mr. Kirkaldy failed. There was no doubt that Mr. Kirkaldy had done a vast amount of testing in the most careful manner, and, having watched him at work, Mr. Snelus could testify to his extreme care. Kirkaldy did all his own work personally, and checked all results himself at the machine, never trusting an assistant to register results; but, as Mr. Snelus had told Kirkaldy many years ago, he ought to connect with the mechanical tests the chemical composition and the physical characteristics of the material. They wanted all these combined before they could draw proper conclusions. They ought to have the chemical composition and the physical characteristics, with microscopical and other observations, to compare with mechanical results. The suggestion to form an International Commission to decide modes of testing, &c., was a good one. At present they had one engineer telling the manufacturer that his material must bear a certain tensile strain in ten inches of length, and another in eight, and perhaps a third in two inches. They all knew that the length of sample used made an enormous difference on percentage of extension, &c.; and therefore it was desirable that this Commission should, if possible, be carried out, and come to some definite conclusion as to the shape and length of the samples, and every other condition under which tests were to be carried out.

Mr. **Bauerman** (London), while agreeing with the preceding speakers as to the desirability of leaving the carrying out of tests in England to private individuals, did not think that there was much force in the objection raised as to the status of the actual manipulators in public institutions. A private professional man of sufficiently high reputation to create a large business would be obliged to employ assistants in carrying out his work, and the probability was that the choice of such assistants would be made under a proper sense of responsibility; but there was no reason to suppose that any less care would be exercised by the heads of a public institution, such as that described by Dr. Wedding, in the selection and control of their subordinates. He agreed with Mr. Snelus as to the importance of accurate investigations of the physical structure of the materials tested by microscopic and other methods where a wide field of inquiry was possible. The subject was no doubt a difficult and obscure one, but he considered it to be of such importance as to be well worth the attention of the younger members of the profession as a special line of work. He should like to know from Dr. Wedding whether the improved analytical processes described as in use at the Institution were published or not?

Mr. Daniel Adamson bore testimony to the value of Dr. Wedding's paper. One speaker had given Sir William Fair bairn full credit for mechanical testing which was largely due to Tredgold, Barlow, and others; and subsequently Mr. Kirkaldy had far surpassed his predecessors in the accuracy of his mechanical-test investigations.

Mechanical tests alone were, however, of little value, unless combined with a full knowledge of the chemical composition of the metal under examination, together with a complete record of the endurance of iron or steel after it had carried its maximum load, as when local elongation set in, less and less weight was required down to the point of rupture.

This latter record, from the maximum load downwards, explained in a large measure the ductility of the material. By using testing machines of a very high power, with the end of the registering level floating through a space of not more than two inches, they could secure a sensible record of a test-piece, ten inches in length, of one-hundred-thousandth part. In this way they could follow down the breaking load of the material as the sectional area diminished, and thus secure the most accurate record of the indication of ductility of the metal, and generally of its malleability also.

These latter records were indispensable when testing metals to be used for large guns for artillery purposes, and were a check against the use or abuse of tempering steel in oil, with a view to improving the metal to resist sudden shock.

This was the operation adopted at Woolwich for the tempering of metals for large guns; and Sir William Armstrong, in his paper read at Southampton before the British Association this year, recommended the same operation. Such a system, however, could not be recommended according to Mr. Adamson's investigations.

It was true that by tempering mild steel in oil they developed an increase of strength, and the metal, when mechanically tested, would carry a greater maximum load. But if this was the only condition required, more power could be obtained by tempering in hot water, or they could get a further increase of strength by tempering in cold water. In each case, however, by increasing the maximum strength of the metal, they more than correspondingly reduced its ductility and power of resisting a concussive force or sudden shock. His own view was, that so long as they continued to construct guns the metal of which was tempered in oil, although they would have increased maximum strength, they would have greatly reduced endurance and reliability.

To increase the maximum strength by any method of hardening was of small value compared with the diminished power of the metal to resist a concussive or percussive force.

After having got a record of the composition of iron or steel to be tested, it was certainly equally necessary in mechanical testing to treat the specimen under the same conditions as when it had to be put to work, whether that was to carry the greatest possible and a steady load, or to resist an irregular intermittent action or violent percussive force. Hence no good could arise from tempering in oil or in water, unless the material to be used for practical purposes could be treated in the same way, and be in reality improved thereby.

Professor Åkerman, in his paper on the tempering of metals discussed at Düsseldorf, supported the system of tempering in oil. In the discussion of that paper, Mr. Adamson submitted that tempering in oil did not, as a rule, improve a mild steel; such, at any rate, as he had had the opportunity of investigating. In reply to that, Professor Åkerman said that he ought to have stated that the improvement took place by tempering Swedish steel in oil. Since that time Professor Åkerman had kindly sent Mr. Adamson a number of bars of Swedish metal, varying in composition, all of which he had carefully tested after tempering in oil—the bars in question being one inch in sectional area—and he had found to his surprise that, without exception, the tempering in oil reduced the ductility of the metal, the Swedish steel following the same law as ordinary Bessemer, Siemens, and Siemens-Martin metal made in England.

With reference to the dimensions of pieces to be subjected to mechanical testing, he considered two inches in length to be utterly impracticable, and when such pieces were of small diameter, say about one-third of an inch in area, misleading, as, in the former case, the whole of the breaking elongation was barely covered by the full length; while to be governed in the application of metal of large sectional areas by having the small pieces tempered in oil or otherwise could at best be only misleading, as the cooling influence on the small area was not indicative of the influence in cooling on the larger sectional area.

All those who recommended tempering in oil from such small specimens mechanically tested incurred a grave responsibility, and one which they would do well to reconsider before tempering metal in oil for practical application.

He had given this subject considerable attention, having quite lately examined nearly two hundred specimens both chemically and mechanically; and had not sickness suspended his operations, the results he had arrived at would probably have been laid before the scientific public ere now.

Mr. **Jeremiah Head** observed that he understood the main question raised by this paper was whether it was desirable that testing should be done by Government or an independent public establishment of some kind, or whether it should continue to be done in various private establishments; also, whether the amounts and nature of tests to which different materials should be subjected should be fixed by an International Commission, or left to the varying ideas of unassociated individuals? He thought this question was of the utmost interest and importance to all who made those materials into the composition of which the metal iron entered. This question of testing was, indeed, more or less a sore subject with almost every producer of iron. At present in England tests were mostly stipulated by civil engineers, and their ideas of what was reasonable and necessary were so various, and in some cases so absurd, as to make it clear that many of those who specified them did not understand what they were doing—at all events, not so well as the producers of those materials. He thought that there was a very great advantage in having a recognised public testing institution. He had been over Kirkaldy's place a little time ago, and was shown some strips of iron sent to be tested by civil engineers or their subordinates, which Mr. Kirkaldy had refused to test at all. This was because they were badly or roughly cut, or had obvious defects in them, or holes drilled out of the centre. Had they then tested and failed, no doubt the blame would have been put upon the material. It was, therefore, manifestly in the interest of the producer of the materials, as well as of the consumer, of the engineer, and of all concerned, that testing should be done by some public officer who should thoroughly understand the business, and whose independence and fairness should be above all suspicion. All would then know that any tests made would be properly carried out. It not unfrequently happened that the producer was told that his materials had been subjected to the guaranteed test and had failed, and that it was rejected. He was not told how the pieces were cut, how tested, or by whom, and he was not even made certain that the material in default was his own manufacture. Still, if he sought farther information or doubted the result, he met with such difficulties as soon forced him to acquiesce, and look upon the first loss as the least. All this was manifestly unfair, and might be avoided by some public testing-place where the test-pieces were cut out as well as tested. The public tester would also make sure that the maker's brand was on the piece sent to him to test, and that the test-piece was marked in a corresponding manner. He wished it to be clearly understood that in advocating public testing-places he was not advocating that Governments should undertake the task, for the simple reason that Governments (at all events the English

Government) had the greatest possible difficulty in dealing with the legitimate objects for which they existed, and anything which could equally well be done independently of it should certainly not be undertaken by the State. He would suggest that the tests that materials could properly be expected to stand should be named by the producers of those materials themselves, rather than by the engineers under whom they were to be used up. If this plan were adopted, the engineer would say to the manufacturer, "I want certain conditions, and should like to get such and such tests, but I ask you to tell me what you can guarantee. I apply to you, the maker of the material I want, in the belief that you ought to know more of the capabilities of your own material than I or any one else. Submit to me tables of tests and analyses of your different qualities, with the extra cost of higher ones. I will then choose my tests from your information and hold you to them." This would, after all, only be doing what is done in every produce market where the seller submits a small sample and the buyer holds him responsible that the bulk shall be in accordance therewith. Engineers having got manufacturers' own tables of tests, could then with confidence put those tables into the hands of their principal draughtsmen to work to. The responsibility of makers would be much more increased if put upon their honour and reputation in this way, because, if the material failed, the engineer could say, "These are your own tests, which you yourself said were reasonable, and which you undertook to fulfil." At the present time a certain amount of feeling was current among iron and steel manufacturers that many of those who specify the tests to which they have to work are less well-informed as to the capabilities of those materials and less reasonable in their demands, than they might fairly be expected to be. Unreasonable demand on the part of engineers or consumers had also the bad effect of encouraging what might be called "diplomacy" in dealing with inspectors, instead of honestly and faithfully fulfilling reasonable obligations. He thought that the suggestion of this very valuable paper, that an International Commission should be formed, was one that should not be lost sight of. He would himself suggest whether the Iron and Steel Institute was not a proper body to appoint a technical commission to consider the whole question of tests, with the view of eventually informing the civil engineering world what in their opinion it was practical to obtain and what it was not. He should like to add, that although the tests of civil engineers were often almost impossible ones, they were also not unfrequently, and at the same time, extremely vague in certain directions, and in others overlooked important points. He remembered a specification where the wrought-iron plates were all to be capable of being bent to a right angle cold without fracture. That seemed so great a test that no manufacturer would undertake it. He called on the engineer and explained this. The engineer replied, "I will show you a piece of common iron which bent to a right angle without difficulty." And he took up a large piece of scrap, bent to a right angle truly, but round a radius of six inches! That was what he called being bent to a right angle! The Admiralty specified that iron for their use should bend to certain angles, but always round a half-inch radius. Again, it was very rare indeed that any elastic limit was specified; yet iron or steel for any purpose whatever was of necessity only made use of within its elastic limit. Therefore the most material point of all was the elastic limit, provided only there was a reasonable margin above it to avoid danger of sudden failure.

Again, it was well known by those who were accustomed to test iron or steel up to the breaking-point, that the principal part of the elongation of the test-piece took place just above and below the point of fracture. The shorter the piece tested, therefore, the greater would be the elongation *per cent.* of the whole length. Nevertheless, engineers often stipulated elongation per cent., but seldom the length to be tested. Lastly, the tensile strength and elongation and contraction of area of iron plates depended mainly on the quantity of work upon the iron in that particular direction. The amount of work attainable depended on the shape of the plate, which was seldom known to the manufacturer when he was forced to undertake the tests. The engineer afterwards made up his mind as to the dimensions of the plates, and usually settled some of them, so that the tests were impossible. All these things were usually quite ignored; but if a technical committee of that Institute were to investigate and report, they would probably point out that the tests obtainable were very much influenced by those considerations, and therefore they must not be disregarded. He should like to say that he did not think that strong and rigid tests made compulsory by Government would be for the good of the public. The public ought to be allowed to use inferior material if there was no deception about it. To say that nothing should be used except those materials that stood the very highest tests would certainly prove a great burden upon industry generally. For instance, if it were laid down that no oranges should be sold with a single speck upon them, the public would not consume the oranges that they did; for they would not pay three or four times the price because a paternal Government did not wish them to eat oranges with specks upon them. He thought, in the case of the iron shipping property belonging to Great Britain, that iron ships would never have been as cheap as they were, and the trade would never have been as large and important as it was now, if the inspection of all the iron used in their construction had been as rigid as they now made it for steel. It was simply because Lloyds' Committee had taken the sensible view that, provided the iron was good enough to work up into the construction of ships, it was good enough to stand everything short of collision and going on rocks; and that being so, they had the extremely satisfactory result of cheap ships and Great Britain monopolising the great bulk of the carrying trade of the world.

Professor **Kennedy** (of University College, London) said that it was with great pleasure and interest that he had heard a gentleman with so great a reputation as Dr. Wedding describe in such detail, and in such a clear and concise manner, what was being done in the German Empire in reference to testing the quality of the materials used in engineering construction. In England, as everybody knew, these matters had hitherto been left to private enterprise. Mr. Kirkaldy, who he thought might be called the father of testing, probably not only in England but also in Europe, had worked always on his own personal account, entirely unconnected with any Government department or office. The success of his work had no doubt been largely due to the personal care and accuracy with which it had always been carried on. It was certainly a question whether these things were not better left in this way, to be carried out by one man, than placed in the hands of a Commission. The members of the German Commission were gentlemen of great reputation. It was obvious, however, that the actual work could not be carried out by them personally, but would be placed in the hands of their subordinates, who would be really responsible for its accuracy, and who, after all, were not likely to be more worthy of trust, more accurate, or more independent of improper influences, than non-officials whose whole credit depended on their status in these respects. He had made many experiments on the influence of form on specimens, as well as of degree of finish in specimens of the same form, and had always found the natural irregularities of the material to be greater than any differences distinctly traceable to those causes, so long as nothing absolutely irrational (such as using square necks or sharp internal corners, &c.) were done in shaping the specimens. The same statement applied also to the method of holding the pieces, about which there had often been so much controversy. For the ordinary purposes of determining limit of elasticity, breaking load, final extension, and so forth, it would be absurd to lay great stress on small differences in these matters, however minutely they had to be considered in cases where the modulus of elasticity had to be determined, and the small extensions occurring below that limit had to be measured. With reference to the contraction of area, he mentioned that Professor Bauschinger of Munich was at present exhibiting at the Nuremberg Exhibition, in his extensive collection of tested specimens, a very interesting case of over a hundred pairs of fractures (by tension), showing the influence of different descriptions of defects on the elasticity of the material. Each pair, one sound and one unsound, was cut from the same piece, and they showed very strikingly a fact which they were, of course, more or less familiar with, that these defects, when small, had very much more effect on the contraction of area than on the tensile strength. They had, indeed, shown themselves distinctly in the former respect before any change was visible in the latter. Whether or not they agreed with Dr. Wedding as to the advisability of the Government undertaking the control of testing Institutes in England (and he, for one, did certainly not agree with him), there could only be one opinion as to the value of the work he had done, and of the information contained in his paper and its equally valuable Appendix, and English engineers would do all they could to profit by both.

Dr. **Wedding**, in reply, said he was far from denying the great value of private researches, such as those made by Kirkaldy, Bauschinger, Tetmajer, and others. A great many truly scientific men had made very valuable and important researches in the same fields which the Royal Institutes cultivated; but he thought, notwithstanding, that all this was piecemeal-work. To get general results it was necessary that Government should interfere. For instance, in case of an accident on a railway, the railway company would not readily give to a private individual the broken material, which could perhaps furnish the argument and facts required, for if the material were found bad, then the railway company would have to pay for the accident. But when all railway companies were *bound* to send broken materials to a State Institute, which tested them with impartiality, the result would be an enormous gain to the general welfare. Then as to the difference in the testing machines and the manner of testing, he believed that there were so many points to be carefully considered, that it would be necessary to work first under thoroughly equal circumstances, as far as possible. On that account he recommended *one* Institute, and this could be, of course, only in the hands of the State.

With regard to the mode of research in the Chemical Institute, everything was public, and any gentleman who wanted to see the arrangements would be welcome at either of the Institutes in Berlin. He could say for himself that he should be most happy to show visitors all that was to be seen, and to gave the fullest possible information on all points.

The **Chairman** said their thanks were due not only to Professor Wedding, but to the gentlemen who had taken part in the interesting discussion that had followed his paper. With regard to the undesirability of having a uniform system of testing, Mr. Adamson spoke from very great practice, and no doubt he had very good reasons for deprecating a uniform system; but Mr. Bell would urge upon those gentlemen who adopted mechanical tests and chemical analyses together to adopt also uniformity of measurement. He did not know anything more embarrassing in ascertaining, for example, the power of resistance, than having to compare the results tabulated in English and in metric measure, *i.e.*, per square inch and per square millimetre. Therefore some uniform system of measurement should be adopted by any Commission or any body of gentlemen who might undertake to bring this matter more prominently before the public. No doubt the field was one of enormous extent—so great that it might deter many gentlemen from entering upon it. It was also, no doubt, a question of a complex character. They had not only chemical considerations, but molecular structure to take cognisance of, which might be altered and modified by a great many considerations and conditions. The temperature at which the metal cooled and the stress to which it might be subjected before it came to their hands was a matter which perhaps had not yet received sufficient attention. Dr. Wedding said something with regard to the effect of persistent concussion. One blow of a hammer might not break a pig of iron, nor two blows, but possibly four might. That went to prove that the material under examination had undergone a certain change of condition by reason of the previous blows, which had not, however, sufficed to produce fracture, while the fourth blow did. The question was—At what point did that start? Would an infinite multiplicity of blows of very small impact in time produce fracture? There was a general opinion amongst engineers that railway axles after a time were not to be trusted in consequence of the alteration caused by long use. A late President of theirs, Mr. Menelaus, whose experience and judgment in those matters no one would venture to dispute, great admirer as he was of steel, once informed him that nothing would induce him to make a fly-wheel shaft of steel, in consequence of the great disposition of steel to be altered in the way to which he had alluded. Further, he had been told that the propeller shafts of steamers were constantly being changed; and he had been informed by the Atlantic companies that they never ran a screw propeller beyond a certain number of years. All these were matters requiring careful consideration and investigation by those who felt an interest in the subject. Upon a railway with which he was immediately connected, they made a point of examining every rail that broke, and they analysed specimens of all the rails which were taken out after a certain number of years. He should be very happy, if any such committee were appointed, to endeavour to place those analyses at their disposal for examination. It was only by a record of such experiences that they could hope to come to any sound conclusion. The Chairman concluded by moving that the best thanks of the meeting be given to Professor Wedding for his valuable paper.

The motion was adopted by acclamation.

The following paper was then read:—

NOTES ON THE MANUFACTURE OF SOLID STEEL CASTINGS.

By A. POURCEL, Terre-Noire.

As is well known, the Terre-Noire process is being successfully applied in England, Sweden, and America. The studies still continued at Terre-Noire are now being directed to two points in the process:—

1. The manufacture of large castings.
2. The methods of annealing and tempering to be applied to the metal, in order to give it all the mechanical properties corresponding to its chemical composition.

The end in view is the substitution of steel for cast iron in all pieces of mechanical construction. But the final solution of this problem is still a long way off. The production of castings of any form and of any dimensions in steel of a well-determined chemical composition, combining the resistance and rigidity of steel with the smooth surface and homogeneity of iron castings, is a very complicated problem, and one which presents material difficulties of more than one kind.

The last progressive step made at Terre-Noire is worthy of notice. An engineering firm in Paris required some cylinders of cast steel, having a diameter of 2·04 metres, and a height of rather more than 2 metres, with a uniform thickness of metal of 50 mm.

These cylinders were to support an internal hydraulic pressure of forty-five atmospheres, without showing any sign of percolation.

The annealed metal was to have a minimum resistance of 50 kilos. per square millimetre, and a minimum extension of 8 per cent.

Of these cylinders six have already been cast. The external surfaces of the castings are quite as smooth as if made of cast iron, and yet the metal is comparatively soft. It contains on the average—Carbon, 0·65 per cent.; manganese, 1·00 per cent. to 1·20 per cent.; and silicon, 0·25 per cent. to 0·30 per cent. It is, in fact, the quality demanded for rails by one of the French companies.

The flanges of the cylinders, after turning, took a very fine polish, even at the gits, and were free from any defects. The metal is cast in moulds of loam, pierced with numerous holes to allow the gases to escape, and dried with great care. It is run in at the top of the mould, and not at the bottom, the time occupied in casting being less than two minutes. This particular point should be noticed.

But it would not be out of place to ask my friend Mr. James Riley for some information on the manufacture of steel castings by the Terre-Noire process, which was introduced by him at the fine works at Hallside in 1878. In the hands of skilful and intelligent moulders such as the English, and in a works commanding such technical ability as those of Hallside, some progress must have been achieved in the manufacture of steel castings, which would certainly be as interesting and valuable to the Iron and Steel Institute, as the very modest details which I have just given.

The second point upon which the experimental studies of Terre-Noire are being directed, comprises the various methods of annealing and tempering, applied for the purpose of assuring the molecular transformation of the metal, and of establishing the equilibrium of the molecules of a casting of prescribed form, and consequently of enduing it with the highest mechanical qualities corresponding to the chemical composition of the metal. We have here to conquer difficulties, not only purely mechanical, but others which are inherent in the solution of every problem pertaining to the domain of physics. You may make lots of experiments and possess numerous results, but it would nevertheless be imprudent to formulate a law which would not be, as every physical law should be, the synthetical expression of the deductions obtained from a very large number of concordant facts. It may, however, be of interest to the Institute to learn the practical results obtained in what is considered an extremely delicate manufacture, that of hoops (frettes) for cannon. More than two years ago, Terre-Noire supplied to the French Navy a considerable number of hoops for guns of 10 centimetres. To-day we are working on an order for hoops of the same type, the specifications for which are more severe. I am only speaking of round hoops, which are of the following dimensions:—

External diameter	360	millimetres.
Internal diameter	246	,,
Thickness of metal	57	,,
Height	265	,,

These hoops are cut out of a round ingot of 385 mm. diameter, cast solid in an iron ingot mould, each ingot furnishing several hoops. The method followed in this class of manufacture is that illustrated at the Paris Exhibition, and consists in casting an ingot, having pretty nearly the external form of the finished casting, and then cutting out the surplus metal by means of powerful mechanical tools, in order to give the piece its definite form. In most cases, the rough casting would possess the dimensions of a rough forging; more metal is, however, generally left to be removed in the lathe. The metal in the head of the casting is of course not here taken into consideration.

A hoop is chosen from each ingot, sometimes from the top, sometimes from the bottom, and sometimes from the middle, from which are taken the samples for drop and tensile tests. This test-hoop is given rather more height than the others, viz., 310 mm. instead of 265 mm. The test-hoops are treated in the same manner as all those of the cast to which they belong, *i.e.*, they are heated and tempered in oil according to a definite formula, and the test cylinder (rondelle d'essai), about 40 mm. high, is then cut in the lathe, and forwarded to the Government works, where it is prepared for and subjected to the drop and tensile tests, a summary of which follows. I will pass over the very minute tests to which each hoop is subjected, my wish being merely to place before you the intrinsic quality of the metal.

1. The bar to be subjected to the drop test is of square section, 30 mm. + 30 mm., and 180 mm. long. It is placed on two supports or knives 160 mm. apart; the anvil weighs 350 kilos.

and the monkey 18 kilos. This bar must stand without breaking fifteen blows at least of an 18-kilo. monkey falling from a height of 2·75 metres.

2. The bars to be subjected to tensile tests have a diameter of 13 mm. and a nett length of 100 mm. The minimum conditions to be fulfilled are—

Limit of elasticity, . .	30 kilos. per square millimetre.
Breaking strain, ...	56 " " "
Extension measured after rupture,	14 per cent.

Between two bars from the same hoop a variation of 6 kilos. per square millimetre is allowed in the limit of elasticity, and 7 kilos. in the breaking strain. The following table contains a certain number of results obtained at Terre-Noire with cast steel hoops made during the present year *—

Nos.	L	R	a'	$\frac{S'}{S}$	N	F
1.	39·4	66·0	16·6	0·74	24	31·0
2.	39·0	65·5	16·8	0·72	29	31·8
3.	41·8	67·5	15·6	0·715	29	31·4
4.	40·3	66·7	14·9	0·66	29	31·6
5.	36·1	61·7	17·9	0·55	29	32·8
6.	39·3	66·3	15·4	0·70	36	31·0
7.	37·2	63·6	18·3	0·56	34	32·0
8.	38·5	65·2	17·3	0·64	35	32·0
9.	38·0	64·8	20·1	0·52	45	31·8
10.	40·0	66·7	17·6	0·55	42	31·0
11.	38·9	65·1	18·1	0·54	41	31·7
12.	39·3	65·9	17·3	0·54	36	31·6
13.	40·8	68·0	13·2	0·68	45	31·0
14.	39·8	65·6	18·0	0·55	47	31·5
15.	38·3	64·5	17·2	0·53	36	33·0
16.	37·5	63·1	16·1	0·68	28	32·5
17.	37·4	62·6	14·9	0·64	26	33·0
18.	38·5	64·2	14·4	0·72	27	36·0
19.	37·9	63·0	16·7	0·52	42	?
20.	36·0	56·6	24·2	0·50	25	40·0

* L represents the limit of elasticity.
R " the breaking strain.
a' " the extension.
S being the original section, and
S' the section after rupture, then
$\frac{S'}{S}$ represents the contraction.
N " the number of blows required to effect rupture by the drop test.
F " the deflection in millimetres measured at the fifteenth blow.

(*N.B.*—The contraction is usually estimated in England by $1 - \frac{S'}{S}$.—*Translator.*)

Each of these figures represents the mean of two tests, in which the differences observed in the limit of elasticity and the breaking strain varied from 0·1 kilo. per square millimetre to 1·6 kilo. Tests Nos. 9, 10, 11, 12 are those of hoops which had been tempered three times in oil. No. 13 has a somewhat low extension but a high breaking strain. A charge is occasionally produced giving a breaking strain of 70 kilos. or more, and an extension of less than 13 per cent. In this case the series of hoops to which this tested hoop belongs are again heated and tempered in oil at a temperature lower than that at which they were previously tempered. By this means the extension is considerably increased, without diminishing the breaking strain too much. On the other hand, when the breaking strain is too low and the extension high, the new tempering is effected at a higher temperature than the preceding one. In regular working, all the hoops are heated to a yellow oxidising colour (couleur du jaune oxydant), and at that temperature are plunged into a given weight of oil in the direction of their axes. They are allowed to cool in the oil, and are reheated at a temperature varying from bright cherry-red to a dull cherry colour, according to the chemical composition of the metal, and then tempered again in a bath of oil, in which they are allowed to cool.

The first tempering transforms the crystalline grain of the metal into a fine homogeneous grain; the second determines the molecular equilibrium of the casting which corresponds to the chemical composition of the metal, and should be more or less intense, according as the metal contains more or less than 0·3 per cent. of carbon and 0·5 per cent. of manganese.

The chemical composition of the metal suitable for this delicate manufacture is comprised between narrow limits. The carbon varies from 0·28 per cent. to 0·32 per cent., the manganese from 0·60 per cent. to 0·45 per cent. The sulphur can scarcely be detected, and the silicon is pretty nearly constant between 0·15 per cent. and 0·20 per cent. I have no wish to enter into any theoretical consideration of the tempering in oil. I will merely observe that the word tempering (trempe) which I use does not imply the idea of a hardening action; consequently, to speak more correctly, I should say immersion.

Moreover, from a theoretical point of view, I share the opinion of my valued friend Mr. Åkerman. But when facts speak for themselves, any one is at liberty to draw his own conclusions in explanation thereof; that in no wise disturbs the facts.

A more serious objection that might be taken, and to which no direct reply can be made except by well-established facts, relates to the question whether hoops of larger calibre, manufactured in the same way as the preceding, would yield equally good results. It may be admitted that hoops for guns of 42 centimetres can be made successfully by the Terre-Noire process, since the experiments made in 1878, specimens of which were shown at the Paris Exhibition, were perfectly successful. But can the methods of heating and immersion in oil, applied to hoops of 10 centimetres, be equally well applied to guns of greater calibre? I firmly believe that they can. In fact, when steel hoops or coils are forged under the steam-hammer, the hammers used for 42-centimetre coils are relatively much larger than those used for coils of smaller calibre. There is a greater expenditure of heat and mechanical force. Well, then, to effect the molecular transformation of a hoop of large calibre in cast steel, and to reduce its molecular condition to as perfect an equilibrium as possible, it is evident that two immersions in oil, under the conditions above mentioned, will not be sufficient. It will probably be found necessary to immerse them two or three times at a yellow oxidising heat, followed by one or two others at a lower temperature, either cherry-red or dull cherry-red. A formula has to be determined for various thicknesses of metal, but the solution of this problem, I repeat, need frighten no one.

Here ends the short statement of the progress recently made at Terre-Noire in the manufacture of solid steel castings, and which the Council of the Iron and Steel Institute have done me the honour of requesting me to write. This brief account, written with the diffidence of an author speaking of his own work, if it does not awaken the false idea that the days of the steam-hammer are numbered, at least affirms again the important fact, that steel can acquire all its mechanical properties by other means than by hammering. I will not close my paper without risking a few words on the famous question of blowholes in steel, which remains, so to speak, a permanent order of the day in the proceedings of the Iron and Steel Institute. I mention, simply as a reminder, that solid soft steel castings are obtained by means of alloys of silicon, manganese, and iron, with a minimum of carbon. Alloys which fulfil that very essential condition of containing but a minimum of carbon, are those in which the silicon and manganese are found in the proportion of their chemical equivalents.* It is very difficult, if not impossible, to attain this with mathematical regularity. I have, however, succeeded, after numerous observations, starting with a burden calculated to a very great nicety, in producing these kinds of alloys of the desired formula, containing up to 13·5 per cent. of silicon and 18 per cent. of manganese. These alloys are added at a red heat to the bath of metal (Siemens-Martin process) immediately before casting. The process is, in fact, the same as obtains in the manufacture of soft metal with ferro-manganese. But the addition of ferro-manganese to a bath of soft metal is followed by a more or less violent reaction, accompanied by a disengagement of gas. With the addition of the alloy of silicide of manganese, on the contrary, the intermolecular reaction is calm. All ebullition is instantly arrested; the surface of the bath becomes quiet, and no gas rises through the slag. It is universally admitted that the gas disengaged from a bath of metal in the middle of the refining period is carbonic oxide. Well, the addition of three or four thousandths of silicon, in the form of silicide of manganese and silicide of iron, is sufficient to instantly arrest this disengagement of carbonic oxide gas. The sample of metal taken before the addition of the silicon is full of blowholes; that taken after is compact and homogeneous. Is this a purely physical action? Is it a sufficient explanation to say that the silicon has determined the solution of the hydrogen in the metal? But, in any case, it is carbonic oxide that is evolved before the addition of the silicon, and little or no hydrogen, according as the manganese is present in small proportion in the bath of steel, or is entirely absent. What is the gas which is evolved in abundance from the moulds when the steel is on the point of solidifying? Sir Henry Bessemer answered that question nearly twenty years ago. It is carbonic oxide, or at least in a great measure. The experiments made at Denain in 1877 by M. Harmet, and others more recently by Mr. Stead, have confirmed this fact. The metal to which silicide of manganese has been added does not give off any carbonic oxide at the moment of solidification, but emits flames of hydrogen, which burn on the surface at the time of casting. These flames of hydrogen gas are more or less abundant in direct proportion to the percentage of manganese. But if the silicon is added in the form of silicide of iron and the steel contains only traces of manganese, there is no disengagement whatever of gas, no matter how hot the metal may be cast.

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* Taking the equivalent of oxygen, according to the old scale, at 100, and silica = SiO_3.

In both cases, however, a steel is obtained free from blowholes, compact and homogeneous. I wish to call attention to this phenomenon, because it seems to contradict the theory of blowholes in steel enunciated by Professor Dr. Friedrich C. Müller of Brandenburg.* Dr. Müller—who by the rather severe manner in which he has treated, or rather ill-treated, what he calls my carbonic oxide theory, has given my views a notoriety for which I cannot but thank him—affirms, as is already known, that the blowholes are avoided by previously effecting the disengagement from the metal of the hydrogen gas which it holds in solution. Now, in the example I am quoting, neither the metal which on solidifying emits hydrogen gas, nor that which does not, has any blowholes. This fact may be easily confirmed by any person who desires to do so, and has perhaps already been observed frequently in works, where the properties of silicon are applied to the manufacture of castings. Is it not also well known that the addition of silicon to the steel not only diminishes the solubility of hydrogen, but almost annuls it, when only traces of manganese are present? Thus we have several samples of steel containing the same quantity of carbon, the same quantity of silicon, *i.e.*, from 0·4 to 0·5 per cent., but in which the proportion of manganese varies between 0 and 2 per cent. All these samples of steel have a compact but crystalline grain, and their fractures do not reveal any apparent cavities. They contain, however, gas, both hydrogen and nitrogen. But, strange to say, the silicon steel with but traces of manganese only contains a very small volume of gas, in which the proportion of hydrogen is very limited; while steel with 0·5 per cent. of manganese contains a very considerable quantity, which goes on increasing in the other samples *pari passu* with the percentage of manganese, until we reach a steel with 2 per cent. of manganese, which contains the largest amount of gas, with the largest proportion of hydrogen. When I first called attention to these anomalies of the theory of the hydrogen blowholes in steel, I was met with the objection that the samples of metal which I had tested were, if not honeycombed, at all events porous, and that steels carefully hammered, which are neither honeycombed nor porous, only yield infinitely small quantities of gas. My answer to this objection is the fact that, in the first place, a metal containing traces of manganese and made with silicide of iron yields no more gas than an ordinary hammered steel; and secondly, the not less important fact, that without having recourse to hammering, cast steels of the composition I have indicated do not yield more gas than hammered steels, when they have lost their crystallisation, and have been reduced by reheating and tempering in oil to a state of perfect molecular equilibrium. One would say, perhaps, that the metal acquires all its mechanical properties by losing the hydrogen which it contains in combination or solution.

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* Dr. Müller's views are set forth in the present volume at pp. 778–780.

Metal made with silicide of iron always remains brittle under drop tests, and gives but low extensions under tensile strain, with a low and variable breaking load. These bad qualities come to light in forging. The metal cracks under the blows of the hammer, whilst metal made with silicide of manganese behaves in a much more satisfactory manner. I will not refer to the explanation of this phenomenon which I have given before. M. Gautier has repeated it very often at the meetings of the Institute.

I should, however, wish to state that I have never offered the opinion that by inter-molecular reaction silicon decomposes carbonic oxide gas, to give rise to free carbon. Mr. Windsor

Richards has already been good enough to re-establish the truth on the subject, and to explain my opinion, which has never varied, viz., "that in the presence of silicon no reaction is possible between carbide of iron and oxide of iron; it is the silicon which is oxidised, and carbonic oxide cannot be formed; and it is a silicate that is the result of the intermolecular reaction." That is what I stated.

I will now close my plea of extenuating circumstances in favour of hydrogen. Dr. Müller, in his researches as to the causes which give rise to blowholes in steel, has drawn a purely judicial conclusion. He found hydrogen in the ingots which he tested, therefore "Is fecit cui prodest." Hydrogen is the culprit; hydrogen causes the blowholes. But is it proved that the proportion of hydrogen increases with the blowholes? Not yet. On the contrary, solid steel contains sometimes as much hydrogen as if it were riddled with the blowholes. And how about the nitrogen? It is innocent. As for carbonic oxide, an *alibi* is pleaded. It certainly exists in the molten steel, and it is again met with when the steel solidifies, and in great abundance when the metal boils in the ingot moulds. Then it disappears. It is not again discovered in the ingot; therefore it is innocent of the blowholes found in the steel. I believe, however, that this judgment is subject to revision.

The proceedings were at this stage adjourned until the following day.

In the afternoon the members visited the Kahlenberg, where they were entertained at luncheon by the City of Vienna. Steamers, provided by the city authorities, conveyed the members over the newly regulated Danube, which was described *en route* by the Burgermeister, city engineers, and members of the Corporation. Salutes were fired from various establishments on the Danube, and flags were hoisted, in honour of the occasion.

THURSDAY, SEPTEMBER 21st.

THE proceedings were resumed this morning in the Hall of the AUSTRIAN SOCIETY OF ENGINEERS AND ARCHITECTS—I. LOWTHIAN BELL, Esq., F.R.S., D.C.L., again presiding.

The CHAIRMAN announced that the Council had telegraphed to Mr. Bernhard Samuelson, M.P., the decision which the members had come to on the previous day, and that gentleman had replied expressing his thanks for the honour of being elected President of the Institute.

DISCUSSION ON M. POURCEL'S PAPER.

Mr. E. WINDSOR RICHARDS, in opening the discussion, said he would be glad to know if the particular method M. Pourcel adopted for obtaining the gas from the steel was that used by Dr. Müller? That gentleman had made some small ingots, got a tank of water, and with the drill passing up through the bore, he drilled a hole from the bottom of the ingot and got the gas from that ingot, and found enormous quantities of hydrogen. He (Mr. Richards) thought there might be some error in operating on small ingots; and he got a large tank made with a drill 2½ inches in diameter, when an ingot of 28 cwts. was placed in the tank and rested on the drill. A hole was then drilled eight or ten inches deep, under water. The gas was then drawn from that hole and enormous quantities of hydrogen were found. He followed up the matter by testing cast iron, in which, also, he found enormous quantities of hydrogen. He took it still further, and had a large forging made under a very heavy steam-hammer, to see if there was gas in wrought iron; and, by operating in the same manner, he obtained similar results. Those great quantities of hydrogen raised a strong suspicion that there was something wrong in the manner of testing. The ingot that had already been drilled was therefore put back into the tank and the cutting edge taken off the drill. That drill was allowed to work twenty-four hours without any cutting edge. At the end of that time the gases were taken off and they still found enormous quantities of hydrogen, although no steel had been cut away, showing clearly that the hydrogen was obtained by the decomposition of the water. He then had some smaller ingots put into a bath of mercury; the hole was drilled as before, but the hydrogen had almost disappeared. He should be glad to know what method M. Pourcel had adopted to prevent a similar error. As to the question of producing solid steel castings, they had been made for more than a dozen years by Mr. Attwood, at Wolsingham, with silico-manganese iron. That iron had been manufactured from the Weardale spathic ores. This silico-ferromanganese pig was placed with scrap in a gas furnace at the commencement of the operation, and no doubt quite solid steel castings were produced in that manner. It was an accidental discovery, and not made known for a considerable time. It was due to M. Pourcel to say that they were indebted to him for the clearer knowledge they now possessed on the subject. He was quite sure that the members would be very much pleased if M. Pourcel would give them a short description of his present method of obtaining solid steel castings.

Mr. G. J. Snelus thought the subject which M. Pourcel had been working at so hard and so long was one of the most important that steel-makers had to deal with. Those who had the charge of Bessemer operations in manufacturing steel knew too well the difficulties of producing sound steel. He had for some time past been trying his best to get the Bessemer steel made at the West Cumberland Works to lie solid in the moulds. All those who were acquainted with the Bessemer operation knew that very often the steel would lie perfectly dead in the mould, and at other times no persuasion would prevent it from boiling over. The only way was to wedge it down, but often with soft steel wedging was not sufficient. Not only was there trouble when the steel boiled over, but the steel which did boil over was very much more honeycombed and produced more unsound rails than that which lay dead. He had known M. Pourcel's method of working, but he had not yet been able to use it for the making of rail ingots. He had succeeded well enough in making solid steel castings, and when they were working special casts, there was not much difficulty in it. But what he wanted to know was whether M. Pourcel had been able to employ anything that was successful in making the steel to lie dead and quiet in the moulds in the ordinary Bessemer practice. He thought it would be exceedingly important and useful to the whole of the steel-makers if they could get this difficulty solved. With regard to the theory which had been propounded as to the cause of unsound steel, he quite agreed with M. Pourcel; and he thought the members would remember that on more than one occasion he had expressed his belief that Sir Henry Bessemer was right when he stated many years ago that the unsoundness was due to carbonic oxide. M. Pourcel's theory, that in the presence of silico-manganese the carbide of iron did not suffer any decomposition, was perfectly right; but there was one point which he had not touched upon, and that was that the fluid steel contained carbonic oxide in the shape of gas. They blew air into the Bessemer converter, and they produced enormous volumes of carbonic oxide. That gas was undoubtedly dissolved in the steel. He felt quite certain that that was the fact, and that carbonic oxide was dissolved in the steel just as carbonic acid was dissolved in champagne. They had to add something to prevent this gas which was dissolved in the fluid metal from escaping and forming spongy steel. Did the addition of silico-manganese cause the steel to dissolve and hold in solution this gas which it already contained? As M. Pourcel said, it prevented the formation of further carbonic oxide; but the question was, did it also engender in the steel a condition similar to the cork in the champagne bottle, which prevented the carbonic acid escaping? He believed that the silicon and manganese added to the metal engendered in the metal something which favoured the occlusion of the carbonic oxide already there, and therefore the steel had no tendency at the moment of solidification to throw off the gas. He was glad to hear Mr. Richards' explanation of the experiments he made, which threw some light upon Müller's discovery of hydrogen.

He never was more astonished than when he read and was given to understand that the blowholes were owing to hydrogen; and as he questioned the truth of the experiments at the time, he was very pleased indeed that Mr. Richards had put it to a thorough test, and found that the hydrogen did not come from the steel itself, but came from the water. That was satisfactory, and removed one difficulty. If they could fix the carbonic oxide which caused the blowholes (which he believed was really in solution in the steel, and not produced by the reaction of the carbide of iron and the oxide of iron), they should gain a step towards securing sound steel, as he had before remarked. There was very little difficulty when making special castings with ferro-silicon and manganese, but there was a difficulty in the Bessemer process in making sound steel ingots, and that difficulty led to enormous waste in their manufacturing operations.

Mr. **Webb** (of Crewe) said they had been lately making a large number of steel castings at the works with which he was connected, and they were now making locomotive driving wheels precisely of the same form as in wrought iron, with the balance weights all cast in. He had got those sound by casting the wheels on turntables. When he started to run the wheel, he ran it in the centre, and he revolved the table very slowly. He got up before he finished the wheel from forty to fifty revolutions in the minute, according to the diameter, till he had run his mould full of steel, and gradually lowered it down again when the mould was full. In that way he got perfectly sound wheels, and he got them as clean as iron castings could be. He made his castings out of a Siemens furnace, and at present he used a pig rather rich in silicon, which he got from Dowlais. But they were now getting ferromanganese with more silicon, and he saw that he should be able to make still better castings. If any of the members of the Institute desired to see what they were doing at Crewe, he would be happy to show them.

The **Chairman**: How much silicon do you use?

Mr. **Webb**: About 7 per cent. I am now building twenty engines with cast steel, which is a first start. The spoke wheel is the type adopted, and I hope shortly to be able to cast the tyre on, and, when that is worn out, turn it off and shrink on a separate one. The skins of the castings are quite as smooth as if they were of cast iron.

Professor **Chandler Roberts** said it was admitted on all hands that the question of the occlusion of gas by metals was one of the most important questions in the metallurgy of iron, and it seemed incredible that the evidence on which it had hitherto rested was so loose. Everybody would remember that Professor Graham was the first to show that both hydrogen and carbonic oxide could be occluded by iron. He always viewed with some suspicion the evidence as to occlusion of gas by metals which rested on merely drilling the metal and releasing the gas; and it seemed to him that if hydrogen were really derived from the iron by such means, it was probably only entangled in blowholes, and not truly occluded hydrogen. It must be borne in mind that the only way to answer the question raised by Mr. Snelus was that of heating the metal *in vacuo* and collecting the gas which was then given off, as merely drilling the metal could, at the best, afford but imperfect evidence upon the question. Care would have to be taken that the iron, if it contained carbon, did not touch the silicious walls of the porcelain tube in which it was heated. It could be shown that the gas was not only occluded, but could penetrate through a considerable thickness of metal; and it seemed to him that the gas actually retained and dissolved by the metal exercised an effect on its physical properties which deserved far more careful study than it had hitherto received.

Professor **Wedding** wished to add some facts which would clear up the effect of silicon on carbonic oxide and confirm the assertion of M. Pourcel. In the Institute at Berlin synthetical trials were conducted, the general result of which was, that if silicon, carbonic oxide, and pure iron are heated together, silicate of iron is got, whilst the carbon united in the whole quantity with the iron as long as the iron was not saturated with carbon, and supposing that there was no free carbon present, as, for instance, is the case in the blast furnace process. It was therefore clear, that as long as silicon was added to nearly pure iron, then all carbonic oxide in solution or mixed with the iron would be reduced in carbon, which united with the iron, as the blisters could not contain any carbonic oxide. He thought it would be quite right to adopt the mode of M. Pourcel if there was not the objection that it was very difficult to get the right quantity of silicon, and not too much; because every one knew the enormous influence which silicon had on the strength of ingot iron or steel. Therefore, it might be in many cases better to leave the blisters in the ingot and only distribute them, which could be done by pressure on the fluid metal. For this latter purpose he thought the best method was that of Mr. Krupp, who gave the pressure by carbonic acid vapours generated from fluid carbonic acid.

Mr. **Bauerman**, referring to the question of hydrogen in steel, said that, in addition to the results of Dr. Müller's experiments, the same thing had been found by several other observers working in different ways. He thought that the fact of the presence of hydrogen in the gases given off by steel when heated *in vacuo* was first published by Mr. Parry of Ebbw Vale.

This statement having been questioned by Mr. Snelus,

The **Chairman** stated that Mr. Parry was one of the earliest observers of the fact.

Mr. **Bauerman** went on to say that hydrogen had been found in a similar manner in the meteoric iron of Tolucca by Mr. Roberts; and in the paper by Mr. Gjers there was evidence of the presence of a large proportion of hydrogen in the gases given off by the ingots in the soaking pits. He thought, therefore, that there was a good deal to be said for Dr. Müller's view.

Mr. J. E. **Stead** (Middlesbrough) remarked, through the Secretary, that he was rather inclined to question the first statement in M. Pourcel's paper, viz., that the Terre-Noire process had been successful in England. His own experience and that of several of his friends was, that although the steel in the open-hearth furnace had the composition prescribed by M. Pourcel, and the process was conducted with the greatest care, and on the lines laid down by that gentleman, the results had been irregular, and not to be relied upon when making small castings. He did not know what had been done at Hallside, and he joined M. Pourcel in asking Mr. James Riley to give them his experience. Sometimes the castings were perfectly sound, but at others (all conditions being the same) they had been sadly honeycombed. The unsound steel cannot have been the results of bad manipulation on the part of the moulders, because the same men obtained superior results when crucible steel was used.

They were led to believe from M. Gautier's first paper on "Solid Steel Castings,"* and from the samples he brought forward, that by following a certain formula uniformly regular results might be obtained, and even small castings free from blowholes be produced. Perhaps they had expected too much; at any rate, it was a fact that, to his knowledge, small castings made from open-hearth steel were rarely quite free from blowholes, and larger castings were very often honeycombed.

There could be no doubt that the Terre-Noire process produced castings moderately sound, but what they expected was steel uniformly free from blowholes, which could be sent at once to the engineer for finishing, without having them returned on their hands by the workmen, with the old story of the "whited sepulchre" on their lips—good outside and rottenness within.

Would M. Pourcel kindly inform them:—1. Whether the castings mentioned in his paper were the product of regular work, or selections from a large number, some or many of which were honeycombed? 2. What proportion of solid castings free from blowholes it was reasonable to expect in using the Terre-Noire process? 3. If there was greater difficulty in making small castings free from blowholes than those of large dimensions? 4. What kind of sand was used in making the moulds, and what were the insides of the moulds faced with?

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* *Journal*, 1877, vol. i. 40.

Turning now from the practical to the theoretical side of the paper, he noticed that M. Pourcel had stated that "no matter how hot the metal when silicon is present, there is no disengagement of gas." There could be no doubt that at lower temperatures silicon did prevent the formation of carbonic oxide, but when the temperature was high enough, carbide of iron was capable of reducing silica with evolution of carbonic oxide. At high temperatures silicon did not prevent honeycombing, therefore at lower temperatures silicon might act on carbonic oxide according to the following reaction, viz.:—$2\ CO + Si = 2\ C + SiO_2$; but when the temperature was elevated the reaction was reversed—$2\ C + SiO_2 = Si + 2\ CO$. They had frequently seen excessively hot Bessemer steel containing 0·3 per cent. silicon and 1 per cent. manganese so "lively" that it was difficult to keep it in the moulds. It was, in his opinion, greatly a question of temperature this producing of solid steel castings free from blowholes, and it was probably the variations in the heat of the steel when poured which might account for the irregularities before referred to. If the steel from a Bessemer converter had just the right temperature, even although silicon was nearly absent, it did not rise in the ingot moulds, and the men had no need to cover the open ends of the ingots; but, on the other hand, if the temperature was greater, the steel swelled up and overran the moulds sometimes, and at others required rapid securing with sand, plates, and wedges to prevent it from doing so. He should like to ask M. Pourcel if he had noticed anything of the kind in working with the open-hearth process?

Mr. JAMES RILEY (Steel Company of Scotland) stated, through the Secretary, that to many of their friends it is well known that they had for some years past given constant and careful attention to this branch of manufacture, the end they had in view being the same as that stated by his friend M. Pourcel, and something more. Besides aiming at "the substitution of steel for *cast iron* in all pieces of mechanical construction," they hoped to do the same with forgings of *wrought iron.*

Recent investigations instituted by one of our great public corporations had demonstrated the fact that, although the *best castings* of steel fell short of steel forgings in the matter of strength and ductility, they were superior in those important qualities to wrought iron forgings. This result he was at present satisfied with, although it fell short of that which they some time hoped to attain—the substitution of steel castings for steel forgings. It was only just to their friends at Terre-Noire to state that in the samples investigated none had been submitted to the "tempering and annealing" process which they so strongly advocated.

In pursuit of their object, they had at Hallside made considerable progress, more especially in the direction of producing intricate and heavy castings. Commencing at first with comparatively simple forms and light weights, they had gained such experience as enabled them to undertake almost anything their friends might require. In their ordinary practice, they were now constantly producing bogie centres, crossheads, axle-boxes, horn-blocks, and other portions of locomotive work; pistons, cylinder covers, crossheads, shafts, and other parts of marine engines; with propeller bosses and blades, as well as castings for numberless purposes in connection with shipbuilding work. In general machine and other work the use of castings was constantly growing. They had, however, done some special work which might be interesting to the Institute. The heaviest casting they had made was a gun-carriage for an eminent firm, for which they charged 28 tons of steel. This carriage and the two girders used in connection with it—castings of 15 tons each—had been machined on nearly all their sides, and would, he had no doubt, completely satisfy M. Pourcel in the matter of being without blowholes. Their latest achievement had been the casting of two stern frames for use in the construction of ships of about 2000 tons gross register. The greatest dimensions were 27 ft. by 13 ft. with boss for propeller shaft 2 ft. 2 in. diameter. One of them was tested recently in presence of members of Lloyds' Committee, and gave great satisfaction. He would invite attention to the results of tensile tests made on test bars cast on the first of these frames, and cut off after annealing was completed. The breaking strain was 33·4 tons, and the extension, measured on 8 in., 14·8 per cent.

After a second annealing the result obtained was 29·2 tons breaking strain, with 23·4 per cent. extension. He knew of no instance on record of such a result being obtained in testing a steel casting. It would be noted that it was equal to what was accepted as a test of good boiler plates. The composition of this casting was C. 0·23, Si. 0·25, Mn. 0·8, P. 0·04, S. 0·03, thus pretty closely approaching the average composition given by M. Pourcel.

It would be understood that the difficulties in the way of tempering in oil prevented them from applying this portion of the Terre-Noire process to such large and heavy castings. In passing, he might say that M. Pourcel did not state that he tempered the cylinders he referred to; doubtless he apprehended the difficulties they had experienced. Also he was at a loss to know why he should have given the steel for these cylinders such high contents of carbon. Certainly this would tend to ensure solidity, but he should have expected this to be gained at the expense of ductility. Besides, it seemed so inconsistent with his usual teaching, and did not appear to be necessary in order to meet the tests required. Would M. Pourcel tell them what results he obtained in the testing, and whether he annealed the castings?

Reverting to their practice at Hallside, he might add that they depended on the Terre-Noire process for giving them the metal they required, but it would be readily understood that the production of such castings as he had referred to demanded something more than this. Great skill was required in the construction of the moulds, especially in the case of intricate castings with cores, and it was a mere truism to say that this could only be gained after much experience and many failures. It might be stated, however, that it was of the utmost importance that provision should be made for the contraction in cooling, which was so great in the case of steel, especially soft steel, that, as far as may be, the casting should be designed so as to give a nearly uniform thickness of metal; or, if this was not possible, then provision should be made for feeding the larger masses of metal in the casting, or they would be hollow and unsound, and that the gates should be so placed as to give free and easy flow to the metal. In Hallside practice, castings of light weight were made in what might be called "green sand," but in all heavy castings it was essential that the moulds be thoroughly dried before casting.

Although, as he had said, they could not make use of the "tempering process" to the extent they could wish, yet they believed it to be very useful when it could be applied, and they had confirmed M. Pourcel's results in very many cases where they had used it.

In conclusion, he would thank M. Pourcel for his too complimentary reference to his Company and to himself, and would venture to affirm that, in view of what was being accomplished by M. Pourcel and others, the final solution of the problem before him was not very remote.

Mr. POURCEL, in his reply, said he would endeavour to answer as concisely as possible the first question asked by Mr. Windsor Richards respecting the description of the process. An account of it had already been given on the occasion of the Paris Exhibition in 1878, and previously, in 1877, by his lamented friend Mr. A. L. Holley.*

The process might be shortly described in the following words:—When they had a bath of metal of the requisite softness, either in the Bessemer converter, the Siemens, or any other furnace, an addition was made of a pre-determined quantity of an alloy composed of iron, manganese, and silicon, with a minimum of carbon, its *modus operandi* being the same as obtained in the manufacture of soft steel with rich ferromanganese, *i.e.*, the alloy was added in small fragments at a red heat. With the addition of ferro-manganese, the soft metal which was produced generally boiled in the moulds, especially in the Bessemer process. In any case, even if the metal were comparatively calm in the moulds, the ingots contained numerous blowholes and was almost spongy.

Sometimes the metal could be obtained calm and free from blowholes by means of a prolonged superheating, when the process was conducted in the Siemens furnace or an open-hearth furnace of a similar kind. In this case, the reaction produced under the prolonged action of a high temperature, between the carbides of iron and manganese and the silica of the walls of the vessel, or of the slag, yielded silicon in indefinite amount, which was dissolved in the bath of metal. It was precisely the same phenomenon that was observed in melting crucible steel, of which the best sorts, those of Sheffield, and notably those of Krupp, contained up to 3 per cent. of silicon, or even more. Sir Henry Bessemer drew attention to this fact at the meeting of the Institute in 1877.* In adding the double silicide of iron and manganese, a metal was obtained which was calm in the moulds, and was perfectly free from blowholes, and, moreover, corresponded exactly to the predetermined chemical composition. In hard steels the silicon did not reach ·3 per cent., and in soft steels it varied from ·1 to ·2 per cent. Nor did the silicide of manganese decompose the carbonic oxide dissolved in the bath. As regards the question raised by his friend Mr. Snelus, M. Pourcel was of opinion that a reaction of this kind may undoubtedly take place. In 1864 Colonel Caron proved that silicon burned in an atmosphere of carbonic oxide, and yielded silica and free carbon. Dr. Wedding had just referred to the experiment of the celebrated chemist Dr. Finkner of Berlin, which completed and confirmed in a striking manner those of the French *savant.* But, as M. Pourcel observed in his paper, it was not necessary to call in the aid of a reaction of this kind to explain the absence of blowholes in the metal produced with silicide of iron and manganese in the Siemens furnace. In fact, the Terre-Noire method consisted essentially in avoiding all refining action during fusion. In the able description of the process given in 1877 by the late Mr. Holley, it was stated that, in order to preclude the oxidising action of the flame, the bath of metal always remained covered with a light green-coloured slag, very rich in manganese.

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* *Vide* Journal of the Iron and Steel Institute, No. I., 1877, p. 86.

The initial pig was a spiegeleisen containing from 7 to 10 per cent. of manganese; the softening materials, iron or steel, were added hot, after being first of all freed from the slight layer of oxide which covered them.

If, for any reason, the slag towards the end of the operation became brown, that was to say, slightly oxidised, manganese was added to the bath. By this means there was little or no carbonic oxide in solution. The double silicide of iron and manganese acted during solidification of the metal to prevent all reaction between the carbide of iron and the oxide of iron which formed during the tapping-out. Instead of carbonic oxide, it was a double silicate of iron and manganese oxides which was formed and separated by liquation. In operating in this manner, it was feasible to use, and consequently to leave, but a small proportion of silicon in the metal, varying from 1 per cent. to 2 per cent. at most, when the product was of a special nature, and had to fulfil well-determined mechanical conditions.

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* Journal of the Iron and Steel Institute, No. I., 1877, p. 81.

Nothing approaching this could be obtained in the Bessemer converter. It was very difficult to obtain a soft metal of a well-determined chemical composition. When the blow was stopped, the metal in the vessel depended upon the nature of the pig iron treated, and especially on the temperature of the blow. There was more or less oxygen and carbonic oxide in solution, and the great quantity of silicide to be used in order to produce a definite result could not be known *a priori.*

Such was not the case in the Siemens furnace, where the temperature could be regulated, and samples of slag and metal taken at any moment to guide the melter. M. Pourcel could assure Dr. Wedding that the greatest uniformity had been obtained with this furnace, and that the difficulties met with in attaining this regularity might always be overcome by a patient and intelligent practical man. In any case, no great alarm need be felt about an excess of silicon which could not exceed a proportion of ·2 or ·3 per cent., *i.e.*, an amount which did not affect the softness of the metal. Crucible steel, which still remained the ideal type of steel, rarely contained less than ·3 per cent. The co-efficient of hardness of silicon was scarcely one-fifth or one-fourth that of carbon. This fact had been confirmed by the scientific experiments of Professor Mrazek and by the everyday experience of Terre-Noire.

Silicon was the indirect cause of the bad qualities observable in silicious steel when it underwent forging, and especially rolling. In fact, every compact, homogeneous, or crystalline solid body, such as an ingot free from blowholes, was very sensitive to sudden transitions of temperature, and did not adapt itself to the rough work of rolling so readily as a spongy ingot. It required more coaxing. It was rolled at a lower temperature, and consequently left the rolls colder; that was, it became strained (*écroui*).

When the piece could be annealed, its molecular equilibrium could be restored. But annealing was not practicable in rail-making, and fractures often occurred which were due to the molecular and not to the chemical condition of the solid. Tensile tests made on samples taken from those rails gave results quite unapproached by those taken from a rail made from a spongy ingot. As regards extra soft steel for ship and, *a fortiori*, boiler plates, he would repeat the opinion he gave to his friend Professor Åkerman in 1878. Silicon should be avoided, not so much as a hardening element, but on account of the homogeneity it gave to the metal. A plate left the rolls in a more strained condition (*écroui*) than a rail, and annealing was necessary; but frequently the annealing failed to restore the molecular equilibrium when the ingot was originally quite free from blowholes. As regarded the theory of blowholes, his wish was merely to bring the question forward; he did not pretend to solve the problem, but would content himself with stating facts, leaving each one to draw his own conclusions.

The analyses of the gases were made by Dr. Müller's method, with all the precautions indicated by Messrs. Richards and Stead, in order to steer clear of the very erroneous results which first of all induced Dr. Müller to believe that hydrogen was present in the pores of the ingot at a high pressure. The method was not free from many sources of error, as Mr. Richards admitted; the results, therefore, had no absolute, but only a comparative value, when care was taken always to operate under the same conditions. He found it more convenient to operate under water, and then, proceeding slowly, to avoid heating as much as possible. The experiment should be so arranged as to pierce holes of the same capacity in a given time in the ingots tested. This was not so easy when operating on metals of different degrees of hardness. In any case, what could be determined was a very marked difference in the volumes of gas extracted from two specimens of metal taken side by side in the same ingot—one rough as cast, and the other annealed and cooled in oil.

The CHAIRMAN said they were always glad to welcome any gentleman from another nation, and particularly when the gentleman addressing them was so competent to do so as his friend M. Pourcel. He was sure they must have listened with very great pleasure to the paper read, and also to the explanatory observations with which the author had favoured them. With regard to Professor Roberts, who had alluded to the manner in which ironmasters occasionally conducted their experiments, they all acknowledged the obligations they were under to Professor Graham for his researches respecting the occlusion of gas by metallic substances; but they could not expect that scientific research would have gone the length of ascertaining (which would have been impossible to one in the Professor's position) the precise effect upon a metal occluding a gas in the manner which Professor Roberts had described. Now that the manufacturer had recognised the important modification which the presence of a very small quantity of foreign matter was capable of exercising upon the quality of iron so impregnated with this foreign matter, they could not doubt that the precise nature of that influence would be very speedily solved. They would be greatly assisted in these investigations when authorities like M. Pourcel, Professor Wedding, and other men of science lent their assistance in endeavouring to ascertain the precise nature of that influence. He begged to move a vote of thanks to M. Pourcel for his paper, which was not only excellent in itself, but had led to a useful discussion.

The vote of thanks was cordially awarded, and the following paper was then read:—

ON COMPARATIVE BLAST FURNACE PRACTICE.

By I. LOWTHIAN BELL, F.R.S.

Many of the members of the Iron and Steel Institute will doubtless avail themselves of the courteous invitation of the ironmasters of the Vordernberg Valley to visit the works of that district.

Our hosts do not possess the means of presenting for our inspection blast furnaces of the colossal dimensions of the modern class, or of showing us appliances for heating the blast up to 1500° to 1600° F. (865° C. to 920° C.); we shall, nevertheless, enjoy the opportunity of seeing iron made with what, at first sight, may appear an almost incredibly small quantity of fuel, in furnaces containing only about 2250 cubic feet, and blown with air at 392° F. (200° C.)

I would only remind you of the costly plant by which we have been able, in Great Britain, to bring down our consumption to something like one ton of coke per ton of metal. Furnaces of 12,000 to 40,000 cubic feet have been erected, and heaters are employed, which, from their construction and size, raise the temperature of the blast pipes to a red heat. Sometimes, indeed, the same plant embraces both these advantages, *i.e.*, it consists of immense furnaces fed with superheated air. In Styria and Carinthia you will find pig iron made with from 12 to 15 cwts. of charcoal per ton, notwithstanding the smallness of the plant and the comparatively moderate temperature of the blast employed.

One marked difference between the practice of the Austrian ironmasters and our own is in the nature of the fuel, theirs being charcoal, and ours in Great Britain coke or raw coal; but although the metal produced is white iron, the quantity of combustible just named may well seem a surprisingly low one.

When my attention was first directed to a study of the operations of the blast furnace, I was greatly impressed with the dissimilarity of the results apparent in smelting iron with charcoal and with coke. This was so striking, that I was at first induced to believe that there was a virtue in charcoal not possessed by mineral fuel; and, if I recollect rightly, this opinion was shared by my friend Professor Ritter v. Tunner, whose able work on blast furnaces, published twenty-two years ago, I recommend to every one interested in the subject.*

Under these circumstances it occurred to me that the action of the blast furnace, considered, to a certain extent, on a comparative basis, might possess some degree of interest upon the occasion of our being assembled in the capital of the Austrian dominions.

To some it may appear rather a waste of time to devote any of our attention to a communication dependent more or less for its interest on the use of charcoal in the blast furnace. In Great Britain, as we all know, the process is almost as little known as is the antiquated Catalan fire; but we must bear in mind that in other parts of the world charcoal pig iron continues to be made on such a scale, that it has been computed that two million tons, or about one-tenth of the world's make, are still produced by means of fuel derived from the forests of those countries where this most ancient mode of making pig iron is still practised. It is, however, a branch of industry which, in most districts, is more or less of a temporary character, for it must, generally speaking, recede as population advances and timber disappears. Nevertheless, I consider charcoal smelting offers sufficient interest to warrant my asking for a few minutes of your time to consider it, not only because you are about to visit one of its most famous seats, but because an examination of any branch of blast furnace work always helps to elucidate the general principles which underlie all.

It would not be easy to single out any manufacturing operation which is carried on under a greater variety of conditions than those which accompany the smelting of iron. Flux and fuel, ore and air, and finally the pig metal itself, differ so much in character as greatly to modify the results obtained in the operation of producing it.

Limestone, the usual flux of the earthy constituents of the ore, sometimes contains as much as half its weight of carbonate of magnesia. Although not without its use in promoting fusion of foreign matter in the ore, magnesia is comparatively inert as regards the important function of removing sulphur from the iron. Hence a very considerable excess of limestone is employed when magnesia is present in large quantity, in order to neutralise the evil consequences attending the presence of this metalloid. The carbonic acid given off by magnesia causes a considerable expenditure of fuel, because it dissolves carbon, involving a loss instead of a gain in a calorific point of view. To show how large a quantity of fuel may be absorbed in the formation of slag, I have estimated that out of about 22¼ cwts. of coke employed in smelting a ton of Cleveland iron, when only using 13½ cwts. of limestone per ton of pig iron produced, the following portions are expended upon the flux:—

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* Théorie des Hauts Fourneaux. Revue Universelle, 1860, 1re Semestre, p. 432.

	Cwts. of Coke.
Expulsion of carbonic acid from the limestone	1·37
Decomposition of carbonic acid by carbon	1·42
Fusion of about 30½ cwts. of slag	4·54
	7·33

The necessity of avoiding the use of a comparatively neutral substance like carbonate of magnesia is sufficiently conspicuous from these figures; and, at the same time, it is obvious that a rich ore, requiring a less weight of limestone and producing a reduced quantity of slag, means a corresponding saving in fuel. To such an extent may this occur, that in certain cases, and with certain ores, under one-half of the quantity of fuel just named is required to deal with the carbonate of lime and to effect the fusion of the slag.

Comparing different cases together, the fuel at one time is charcoal, at another coke or anthracite, and at another raw coal; and different specimens even of the same kind of combustible vary in the amount of ash and other foreign matter they contain. They also differ in the facility with which they are attacked by the carbonic acid produced during the process of reduction or expelled from the limestone.

The ore not only requires a varying amount of heat, and consequently of fuel, according to its content of iron, but demands for its treatment a larger or smaller furnace, according to the readiness with which the mineral parts with its oxygen. One kind of ore, like that of Cleveland, is most economically smelted by being exposed for sixty or seventy hours to the reducing influence of the gases; whereas other descriptions, like the spathose ore of Eisenerz, pass through the furnace in periods varying from five to six hours.

The atmospheric air varies in the quantity of moisture it contains. Sometimes the blast as it enters the furnace may carry with it 1 per cent. of hygrometric moisture, to decompose which, if 140 units of air are consumed per 20 units of iron, 5270 C. calories are absorbed. Reckoning each unit of coke to be burnt with air at about 538° C. (1000° F.), and to give 3800 C. calories, this quantity of moisture represents about 1·38 units of coke per 20 of pig iron. The case just quoted is an extreme one, firstly, because the atmosphere does not usually contain much above half the above-named weight of moisture; and, secondly, 100 units of air instead of 140 is a fair allowance in modern furnaces. With these two corrections, about one-third of the heat just mentioned usually suffices for decomposing the watery vapour entering at the tuyeres. It will, however, be observed that the fluctuation in the quality and quantity of air is such as to involve a difference on the heat required, varying from about ½ a unit to 1⅓ units of coke per 20 units of pig iron produced.

Lastly, the amount of metalloids, exclusive of the carbon in the metal, is occasionally as low as ·2, while sometimes it reaches 3 per cent. This may mean that one unit or more of coke is required per 20 of pig in the latter, against about ·1 unit in the former case.

When the able article by Ritter von Tunner first attracted my attention, I was unable, from want of the necessary opportunity, to compare the behaviour of a furnace using charcoal with that of one using coke or raw coal. During my visits to the iron districts of Lake Superior, Virginia, Alabama, and Georgia, some years afterwards, I was able, from personal observation and from the information kindly afforded me, to institute those comparisons between vegetable and mineral fuel which, under other circumstances, would have been laborious and difficult.

It may be well at this point to remind you that all kinds of carbon do not appear to yield *exactly* the same quantity of heat. The diamond is said to afford 7770 C. calories for each unit burnt to the state of carbonic acid; native graphite, 7797; and the hard lustrous carbon deposited on the inside of gas retorts, 8047. Wood charcoal varies from 7900 to 8080 calories per unit of carbon burnt. After consulting many authorities, I have adopted 8000 calories as the equivalent for carbon in coke; so that, according to this view, vegetable carbon cannot be said to possess any advantage, in a heat-producing point of view, over that obtained from mineral coal.

At one time I supposed it possible that the greater richness of charcoal, as compared with coke, in the alkaline matter which accumulates in a blast furnace might, by promoting the fusion of the earths, or by the conversion of such matter into cyanides possessing a certain amount of reducing power, account in some measure for the small quantity of charcoal required in the Vordernberg furnaces, and elsewhere in the Austrian dominions.

I was never able entirely to satisfy myself as to even the partial soundness of this explanation; and when I found, in the first charcoal furnaces I visited in the United States, that, all things considered, they were consuming about the same weight of charcoal as we of coke, I ceased attaching much importance to the presence of cyanogen compounds. On this question I shall, however, say a few words at a later period.

A convincing proof of the close correspondence of the action of the two kinds of fuel was afforded me in West Virginia, where I found a furnace in which the same quality of ore had been smelted at one time with charcoal and subsequently with coke. Making allowance for the difference of conditions, such as richness of ore, &c., the results afforded by the two kinds of fuel agreed as nearly as could have been expected.

In some localities in the United States, the social changes already alluded to as being unfavourable to the production of charcoal iron have led to the abandonment of many works. The timber-producing powers of North America are, however, still so large that in other places furnaces have been built; so that the make in 1881 exceeded that of any previous year. Ten years ago, viz., in 1872, the production was 500,587 net tons, and in 1881 it rose to 638,838 net tons of 2000 lbs.

The importance of this branch of the American trade has led to the founding of the United States Association of Charcoal Ironworkers, in whose Transactions are many papers of high excellence. One by Mr. John Birkinbine, the secretary of the Institution, gives at considerable length some very interesting results of certain trials at the Pine Grove Furnace in Pennsylvania. In it, using an ore yielding about 40 per cent. of metal, with 11 to 12 cwt. of limestone per ton of pig, they consumed from 22·59 to 23·66 cwts. of charcoal for grey iron, varying from No. 2 to No. 2·40, with a production of about 100 tons per week. The furnace is only 36½ feet high, with boshes of 9·4 feet, blown with air at 600° F. (316° C.)

Having regard to the temperature of the blast, and, above all, to the size of the furnace, this is no doubt very fair work —very much better than the same furnace was able to do with mineral fuel. When coke was employed instead of charcoal, the fuel rose to 31·19 cwts., the limestone to 23·00 cwts., while the weekly make fell to 70 tons of No. 3 quality. When using anthracite, the consumption was 34·56 cwts., with 24·94 cwts. of limestone, the production falling to 58 tons of No. 3.

Speaking roughly, the larger quantity of carbonic acid in the limestone, when using coke or anthracite, would carry off about 1·4 cwts. of carbon, while the decomposition of the limestone and fusion of the slag would account for about 2¼ cwts. more than when using charcoal. We may therefore approximately estimate the addition to the fuel from these two causes to amount to 3½ cwts. on each ton of iron. The greater volume of the escaping gases, when using fossil coal, as compared with that carried off in the case of charcoal, would carry off sufficient heat to account for the remainder of the fuel expended.

By the kindness of my friend, Professor Åkerman of Stockholm, I have been favoured with the particulars of the performance of twenty-seven charcoal furnaces in Sweden, and from these an average of the whole has been compiled.

Particulars of Twenty-seven Swedish Furnaces working with Charcoal.

	Dimensions in English Feet.		
	Minimum.	Maximum.	Average.
Height	30·3	54·6	45·8
Diameter of boshes	6·8	10.6	8.8
Cubic capacity in feet, roughly estimated	600	2,400	1,400

From the information contained in the tables furnished to me, an estimate of the average heat required in smelting in these twenty-seven charcoal furnaces has been made. Alongside of it, for purposes of comparison, I have placed a similar statement showing the calories necessary in smelting iron with coke. In each case 20 units of pig iron are taken.

	Swedish Furnaces.	Cleveland Furnaces.
	Calories.	Calories.
Evaporation of water in fuel	1,631	324
Reduction of iron from ore	31,761	33,108
Carbon impregnation	1,920	1,440
Expulsion of carbonic acid from limestone	1,421	4,013
Decomposition of carbonic acid from limestone	1,472	4,160
,, moisture in blast	1,360	2,444
,, phosph. and silicic acids	522	4,174
Fusion of pig iron	6,600	6,600
,, slag	8,270	14,520
Transmission of heat through walls, supposed	2,543	3,658
Carried off in tuyere water	1,109	1,818
,, escaping gases	6,913	7,542
	65,522	83,801
Estimated development of heat, based on the composition of the gases and fuel consumed, together with heat due to temperature of the blast	63,635	84,772

The fairly close correspondence of the two sides of the account, viz., heat produced and absorbed, is a voucher for the approximate correctness of the account taken as a whole. From this statement it will be perceived that fully 30 per cent. more heat is required for smelting the Cleveland ironstone than is needed for the richer hematites of Sweden.

The consumption of fuel, &c., was as follows:—

	Swedish.	Cleveland.
Cwts. of fuel per ton of pig	19·48 *	20·40
„ limestone do.	3·84	9·38
„ ore	39·56	46·93
Temperature of blast	412° F. = 211° C.	1045° F. = 563° C.
„ escaping gases . . .	552° F. = 289° C.	504° F. = 262° C.

The heat computation was obtained by the following method:—

	Swedish.	Cleveland.
Cwts. of fuel per ton of iron	19·48	20·40
Less water, &c.	3·02	...
	16·46	20·40
Less ash, &c., and, in case of charcoal, less carbon already combined with oxygen	2·12	1·63
	14·34	18·77
Less dissolved by carbonic acid in limestone . .	0·46	1·12
Leaving carbon to produce heat †	13·88	17·65

	Swedish. Calories.	Cleveland. Calories.
Carbon burnt to CO . . .	13·88 × 2,400 = 33,312	17·65 × 2,400 = 42,360
Carbon of this CO burnt to CO_2	4·85 × 5,600 = 27,160	5·48 × 5,600 = 30,688
Heat in blast	3,163	11,724
	63,635	84,772

It is needless to say, keeping in mind the much larger quantity of heat which accompanies the conversion of carbon into carbonic acid than into carbonic oxide, that the larger the quantity of the former compound we have in the gases, as they leave the furnace, the better.‡

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* As nearly as I can make out, twenty furnaces making hard grey iron

for Lancashire fires have an average capacity of	2350 C. feet.
Charcoal consumed per ton of pig iron	18·45 cwts.
Seven furnaces making Bessemer, average capacity	2085 C. feet.
Average consumption of charcoal per ton of pig	20·50 cwts.

† Including the carbonic acid generated by the action of carbonic oxide on the minerals, I find the ratio of carbon as carbonic acid to that as carbonic oxide is as follows:—

	As Carbonic Acid.	As Carbonic Oxide.
Average of sixteen furnaces making hard grey iron	1	2·10
Average of six furnaces making Bessemer iron .	1	2·37

‡ One unit of carbon into carbonic oxide gives 2400 calories, whereas one into carbonic acid affords 8000. In the statement just given the carbon is supposed first to be burnt into the oxide and then this oxide to pass into the condition of carbonic acid, by which we get the 8000 calories (2400 + 5600).

As is well known, the source of the oxygen which has to convert the carbonic oxide into carbonic acid lies in the ore. Besides the acid thus formed, there is a certain quantity given off by the limestone, and a further amount evolved by the dissociation of carbonic oxide, of which two equivalents are resolved into one of carbon and one of carbonic acid ($2\ CO = C + CO_2$).

The moment, however, that the carbonic acid, from whatever source it comes, exceeds a certain limit, depending upon the temperature and other conditions at the spot where its liberation or formation takes place, it is resolved into carbonic oxide by an action the reverse of that just stated, *i.e.*, the oxygen of the carbonic acid attacks the carbon of the fuel, as is expressed by the formula $CO_2 + C = 2\ CO$.

Speaking again from results obtained in using Cleveland stone, to which my attention has been chiefly directed, I am inclined to believe that the limit in question is reached when one-third of the carbon in the gases, at the outside, is in the form of carbonic acid, and the remaining two-thirds in that of carbonic oxide. In practice, however, this proportion appears to be seldom reached; 1 to 2·1, or 1 to 2·2, or even more, being a more usual ratio between the two, while in furnaces of insufficient capacity it often is as 1 to 3, or even more. The figures given in the ascertainment of the heat produced do not exhibit the whole of the carbonic oxide, because there is also that due to the action of the carbonic acid of the flux on carbon, which does not produce heat. With this correction, in the two examples selected for illustration, the ratio is as follows:—

Swedish furnaces,	1	of carbon as	carbonic acid, to	2·05 as	carbonic oxide.
Cleveland do.	1	do.	do.	2·52	do.

Calculated volumetrically, we have 100 volumes of carbonic oxide accompanied with the following of carbonic acid:—

Swedish furnaces, average using charcoal	49 volumes.
Cleveland furnaces do. using coke	39 ,,

It is only right, however, to state, that occasionally, in the list furnished to me by Professor Åkerman, this ratio is considerably exceeded; 60 or 70 volumes, and even more, have been found associated with 100 volumes of carbonic oxide, and at the same time the consumption of charcoal for hard grey iron was as low as 15·54 cwts. per ton.

To illustrate this, I would submit the duty performed by the furnace of Björnhyttan, having a height of 43 feet, with a capacity of 2116 cubic feet.

The heat required is estimated as follows:—

	Calories.	Calories.
Evaporation of water in fuel	2·02 × 540	1,090
Reduction of iron from oxide		32,565
Carbon impregnation	·80 × 2,400	1,920
Expulsion of carbonic acid from limestone	4·42 × 370	1,635
Decomposition of ,, ,,	·52 × 1,664	1,664
,, ,, water in blast	·04 × 1,360	1,360
,, ,, silicic and phosphoric acids	·10 × 522	522
Fusion of pig iron	20 × 330	6,600
,, slag	12·01 × 550	6,605
Transmission of heat through walls, supposed		2,341
Carried off in tuyere water		936
,, escaping gases	78·99 × 222° × 250 SH	4,384
		61,662

The heat developed by the combustion of the charcoal was estimated at 60,915 calories.

The calculation was obtained as follows:—

Charcoal, quantity given as consumed per 20 units of iron		15·44 units.
Weight of 15·44 of charcoal after deducting water, oxygen, ash, and hydrogen, amounted only to		12·08 ,,
Carbon in charcoal as above	12·08	
Less burnt by carbonic acid in minerals	·52	
		Calories.
Burnt to carbonic oxide	11·56 × 2400 =	27,740
Of this burnt to carbonic acid	5·83 × 5600 =	32,648
		60,388
Less ·4 of carbon combined with ·8 of oxygen in charcoal		2,080
		58,308
Heat in blast		2,533
		60,841

The total carbon as carbonic acid per 20 units of iron was 5·43, and as carbonic oxide 6·37 units. The ratio, therefore, was 1 to 1·17 or 85½ volumes carbonic acid to 100 volumes carbonic oxide.

In a recent number of the "Oest. Zeitschr. für Berg- und Hütt. Wesen," is to be found an excellent paper by M. F. Friderici, containing some important information on the subject of smelting iron by means of charcoal at Vordernberg. I shall offer no apology for inserting some of the facts contained in the communication in question, with a view to compare the results with those obtained in Cleveland when using coke.

Vordernberg Furnaces.	Furnace 2.	Furnace 3.
Total height in English feet	35·49	53·13
Diameter at bosh, do.	7·87	12·42
Cubic capacity (c. ft.)	1126	3696
Weekly make, white iron (tons)	105	269½
,, ,, per 1000 c. ft. of capacity	93.2	73·0
Consumption of charcoal per ton (English cwts.)	14·8	12·6

In order to ascertain the circumstances which enable the charcoal smelters of Vordernberg to produce a ton of iron with so small a quantity of fuel, I propose examining the heat produced at the two furnaces in question, and comparing the product with that of a Cleveland furnace, using a very much larger quantity of fuel in the form of coke, and making only 30 tons per 1000 cubic feet per week.

	Vordernberg 2.	Vordernberg 3.	Cleveland.
Weight of fuel consumed per 20 units of pig iron	14·80	12·60	22·32
Temperature of blast	572°F 300°C	842°F 450°C	905°F 485°C
,, of escaping gases	343°F 173°C	446°F 230°C	630°F 332°C

The heat produced in the furnace per unit of fuel as charged was as follows:—

	Furnace 2.	Furnace 3.	Cleveland.
	Calories.	Calories.	Calories.
Combustion of the carbon	3609	3726	3653
Contained in the blast	277	393	534
	3886	4119	4187
Carried off in the gases	222	281	509
Accounted for in the furnace	3664	3838	3678
Difference from Cleveland	− 14	+ 160	

Thus, according to this statement, the heat obtained from the coke is about equal to that obtained from the charcoal in the furnace which works least economically (No. 2), and about 4 per cent. less than that in the larger furnace. This difference is particularly striking when we consider the very different value, from a calorific point of view, of the two kinds of fuel; for while coke contains from 90 to 92½ per cent. of fixed carbon or carbon in the form of combustible gas, charcoal has only about 86¼ per cent. Indeed, after making allowance for the combined oxygen it contains, it will not be safe to reckon it as affording more than 85 per cent. of carbon available for heat purposes.

To obtain the heat-producing power of each variety of fuel, an allowance must be made for ash, moisture, &c., and then a deduction made for carbon carried off by the carbonic acid liberated from carbonate of lime.

	Furnace 2.	Furnace 3.	Cleveland.
Carbon delivered to furnace per 20 units of iron, after allowance for water, ash, &c. .	12·61	10·74	20·40
Carbon carried off, without affording heat, by carbonic acid in flux or ore .	·71	·43	1·64
	11·90	10·31	18·76

The heat evolved is as follows:—

	Furnace 2.	Furnace 3.	Cleveland.
C burnt to CO . .	11·90 × 2400 = 28,560	10·31 × 2400 = 24,744	18·76 × 2400 = 45,024
C of this to CO_2. .	4·438 × 5600 = 24,853	3·964 × 5600 = 22,204	6·52 × 5600 = 36,512
	53,413	46,948	81,536
Calories in blast .	4,103	4,952	11,919
	57,516	51,900	93,455
Calories in escaping gases, including those in ore . . .	3,295	3,540	11,356
	54,221	48,360	82,099

The heat afforded and absorbed in the furnace per unit of pure carbon is as follows:—

Furnace 2 . . . . 54,221 ÷ 12·61 = 4,300
" 3 . . . . 48,360 ÷ 10·74 = 4,503
Cleveland . . . . 82,099 ÷ 20·40 = 4,024

The product in calories per unit of carbon is as follows:—

	Combustion of Carbon. Computed from Oxidation.	In Blast. Computed from Wt. and Temperature.	Total.	Less in Gases and Hot Ore.	Absorbed in Furnace.
Furnace 2 . .	Calories . 4,236	325	4,561	261	4,300
" 3 . .	" . 4,371	461	4,832	329	4,503
Cleveland . .	" . 3,997	584	4,581	557	4,024

These figures indicate a greater loss of heat in the case of Cleveland iron: this arises from more carbon being carried off by the action of carbonic acid on the fuel, as well as from the escaping gases having a greater volume and higher temperature than in the Vordernberg furnaces. On the other hand, each unit of carbon burnt in the Cleveland furnace is accompanied by a much higher amount of heat in the blast.

The superior results afforded by charcoal, in the cases we are considering, are due to the higher state of oxidation of the gases.

In the calculation of heat evolved, as already given, the carbonic oxide generated by the action of carbon on carbonic acid is excluded; but in estimating the composition of the gases, it is necessarily brought into the account. Now, analysis showed the composition of the gases to be as follows:—

	Weight.	Carbonic Acid.	Carbonic Oxide.	Carburetted Hydrogen.	Hydrogen.	Nitrogen.
Furnace 2	100=	22·37	23·84	·37	·09	53·33
,, 3	100=	24·93	23·13	·32	·09	51·53
Cleveland	100=	17·30	25·20	—	·10	57·40

In these, the ratio of carbon as carbonic acid to carbon as carbonic oxide and carburetted hydrogen by weight is:—

	As Carbonic Acid.	As Carbonic Oxide and Carburetted Hydrogen.
Furnace 2	1	1·72
,, 3	1	1.49
Cleveland	1	2·28

In all my experiments on Cleveland iron, and also, indeed, in furnaces smelting red and brown hematite, I have rarely, if ever, found the ratio of carbon as carbonic oxide to carbon as carbonic acid to fall as low as 2 to 1; and I was, therefore, greatly surprised at the results just mentioned. At first I was induced to ascribe the difference to the analysis not representing an average composition of the gases. As is well known, it often happens that an excessive quantity of carbonic acid is given off for a short time from a furnace, particularly immediately after charging; although I consider the excess of heat so generated to be almost entirely useless, being for the most part, in a coke furnace, carried off in the escaping gases. But since the unusual proportion of the higher oxide of carbon appears in both these cases, as well as in others, including one expressly made for me by Professor

Tunner some years ago, I am compelled to regard the occurrence as not being one of an abnormal character. To satisfy myself on this point, I have examined the performance of the furnace; and, so far as I am able to judge, in order to provide the heat required, all the carbonic acid stated to be present in the gases seems to be necessary.

It may be useful to supplement the extracts taken from Mr. Friderici's paper, by quoting the results obtained by observations made at my own request by my friend Professor v. Tunner about fourteen years ago.

Upon that occasion 20 units of pig iron (white) were alleged to be made with 13·20 units of charcoal burnt with air at 400° C. (752° F.)

In order to estimate the heat in the same way as that already adopted, it is assumed that 10·68 units of pure carbon were serviceable; these being calculated as follows:—

Weight of charcoal delivered to furnace	13·20
Less foreign matter 1·98 and C. removed by CO_2 ·54 = .	2·52
Total	10·68

The total weight of the carbon contained in the escaping gases is equal to—

That contained in the charcoal = 13·20 − 1·98 foreign matter =	11·22
That contributed by the limestone	·54
	11·76
Less that combined with the pig iron	·60
	11·16

Of these 11·16 cwts. of carbon in the escaping gases, 4·05 are present as CO_2 and 7·11 as CO; but they contain besides ·44 CH_4+H, so that their reducing power may be roughly represented by 7·11 + ·44 = 7·55; in which case the ratio of C as CO_2 to C as CO and CH_4 may be taken approximately as 1 to 1·87. The heat evolution amounts in all to 51,891 calories, and each unit of carbon in the charcoal therefore developed 51,891 ÷ 11·22 = 4624 calories.

Taken volumetrically and including the CH_4 and H, which is the more correct mode of stating the case, the ratio is about 100 volumes of reducing gases to 52 volumes of CO_2.

Net useful effect from factors just given.

	Calories.
Due to combustion of carbon	4220
Contained in blast	404
	4624
Less carried off in gases	294
Net calories used in furnace	4330

It is always satisfactory, in such calculations as the present, to have the heat evolution checked by the heat absorption. On applying the same figures as those employed on many former occasions, making, of course, proper allowance for altered conditions as to slag, &c., the heat required comes out to be 56,895 calories, showing a difference of (56,895−51,891) 5004 calories. Admitting for a moment that the larger number (56,895 calories) was required, an addition of 1·26, making in all 14·46 units of charcoal per 20 of pig, would suffice for its supply. It has to be remembered, however, that the iron made in the Vordernberg furnace is white iron, whereas we are comparing it with grey foundry pig in the Cleveland furnace. Now the difference between my figures above, representing the absorption of heat for foundry iron, and those which appear as really obtained for white iron, viz., 5004 calories, equal to 9·6 per cent., is by no means greater than might, under the circumstances, be expected for the two kinds of metal.

We still have to reconcile the different ratios of carbonic acid and carbonic oxide found to obtain in these Vordernberg furnaces and in those of Cleveland.

As already intimated, my observations on the conduct of furnaces smelting the ore of the last-named locality have led me to conclude that when the ratio is 1 volume of CO_2 to 2 of CO the mixture of gases ceases practically to act on Cleveland ironstone. The largest average proportion of CO_2 I have found was represented by the proportion of 1 volume of CO_2 to 2·09 vols. of CO. As a rule, fairly good working is obtained when the ratio is 1 vol. of CO_2 to 2·20 of CO.

In three examples of charcoal furnaces referred to in this communication we have 1 vol. of CO_2 accompanied by 1·49, 1·72, and 1·87 vols. of CO.

It has to be borne in mind that, in stating that certain mixtures of these two gases at a given point become exhausted in their reducing power, it is not to be understood that carbonic oxide cannot under any condition whatever rob an ore of any more of its oxygen, when once the resulting gas, which has effected the deoxidation, is charged with carbonic acid to the extent just named.

Suppose a small quantity of the oxide of carbon to be passed through a large excess of ore, then there is no difficulty in converting the *whole* of the gas made use of into carbonic acid. This, however, does not mean the reduction of the oxide of iron to the metallic state; it is merely the separation of the first, and what may be considered the most loosely united, portions of the combined oxygen from the ore.

As illustrating the subject under consideration, I found in the laboratory that a mixture of 100 vols. of CO and 50 of CO_2 at a temperature of 417° C. 782° F., only separated 2·10 per cent. of the combined oxygen in calcined Cleveland stone in 5½ hours, and 10·04 per cent. in 11½ hours.*

At the furnace itself, the results obtained indicated a very languid action when the ratio of the two oxides of carbon approached that just named. Thus 100 vols. of CO mixed with an average of 40 to 45 of CO_2, at an average temperature of 312° C. (594° F.), in twenty-four hours only separated 3·72 per cent. of the oxygen combined with the iron in calcined Cleveland ore.

As an instance of the want of power of certain mixtures of the two gases in question to produce metallic iron, a mixture consisting of equal volumes of CO_2 and CO was passed over iron ores of different kinds, and over pure spongy iron at a bright red heat. As soon as the oxide of iron lost one-third of its oxygen, becoming protoxide, all further action ceased. At the same time the pure iron was oxidised, having also passed into the state of protoxide.

Now, when we compare the ratio in which the carbonic acid, the oxidising gas, and the carbonic oxide, or the reducing element, is found at different levels in a furnace working at Eisenerz and in Cleveland, the difference, according to the analysis of Professor Richter and M. Tunner, is remarkable.

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* In a furnace of 12,000 cubic feet, 80 feet high, the proportions of carbonic oxide and carbonic acid are at the top as 100 vols. to 45, but as we descend the CO_2 rapidly disappears.

	Wrbna, of 2400 cub. ft.	Cleveland, of 6000 cub. ft.
Escaping gases contain per 100 vols. CO . . .	Vols. 57 CO_2	28
About 18 feet from top	48·8	2
,, 28 ,, ...	44·8	5
At the tuyeres	7·7	trace

In the Cleveland furnaces, particularly those having a height of 75 or 80 feet, the gases are remarkable for the small quantity of carbonic acid they contain when taken below a certain level. The following examples, obtained from a furnace of 17,500 cubic feet capacity, are illustrative of this assertion:—

Point of Sampling.	Vols. for CO_2 per 100 of Gases.	Vols. of CO per 100 of Gases.
At tuyeres	·0	35·4
Do.	·0	34·4
Do.	1·5	36·5
Do.	·0	34·8

Point of Sampling.	1st Experiment. Per 100 of Gases.		2nd Experiment. Per 100 of Gases.	
	Vols. of CO_2.	Vols. of CO.	Vols. of CO_2.	Vols. of CO.
16⅓ feet from top	2·22	34·08	2·25	33·31
20 ,, ...	·67	35·11	·73	34·84
39 ,, ...	1·09	34·96	1·00	35·08
52¼ ,, ...	1·51	35·24	...	...
65 ,, ...	·50	35·92	·49	36·03
70½ ,, ...	·00	36·63	·00	37·60
At tuyeres	81	37·70	·73	37·86

Against these figures I will place the composition of the gases in an Eisenerz charcoal furnace, which has a height of 52·65 English feet and a capacity of 3592 cubic feet:—

Escaping Gases.	Vols. of CO_2. Per 100 of Gases.	Vols. of CO. Per 100 of Gases.
Average of two trials	16·02	17·87
18 feet from throat	14·86	19·39
25⅓ ,, ...	13·93	18·77
28 ,, ...	13·87	19·69
32 ,, ...	12·35	20·46
34½ ,, ...	2·98	38·56

No doubt the interior of a furnace presents very different conditions from those in the laboratory experiment already alluded to, or even in the furnace gases themselves. In both the latter cases solid carbon is absent, whereas in the furnace it exists in great abundance.

In the furnace itself, however, the same law holds good as where carbon is absent, although it is modified. Thus certain mixtures of gases are unable to withdraw above a certain quantity of oxygen from an ore. In like manner, certain mixtures of carbon and gaseous oxides of carbon, the latter in certain relations to each other as to quantity, may separate a certain proportion and no more of the combined oxygen.

In both cases particular mixtures might be unable to produce any metallic iron at all; in others a smaller or larger quantity of the metal might be reduced, leaving a larger or smaller proportion of unreduced oxide to be carried off in the slag. This is what in point of fact happens in the two cases we are discussing. The slag from a Cleveland furnace contains often as little as ·25 per cent. of protoxide of iron, whereas in that run from the Vordernberg furnaces 3·25 per cent. is found.

In the experiment with equal volumes of CO_2 and CO, a position of static equilibrium is reached when the iron is reduced to the condition of protoxide. In the Vordernberg furnace a similar state of things obtains only when all the iron is reduced to a metallic condition, except that portion which, as just described, is found in the slag as protoxide.

All the figures to which I have had access seem to prove that charcoal possesses no superiority whatever, from a heat-producing point of view, over coke; and that its apparent economy in the production of a ton of pig, in manufacturing either white or grey iron, is due exclusively to the quantity of heat required being less than that in those coke furnaces with which it has been compared.

Although a given number of units of the two kinds of fuel may afford the same quantity of heat, there are, nevertheless, unquestionably some differences in the mode in which the needful heat is developed by the two kinds of fuel which merit notice.

My own experiments, and those of Professor Åkerman, prove that coke and charcoal as they are charged into the blast furnace are readily affected by heated carbonic acid. Both sets of experiments point also clearly to the fact that charcoal is much more readily acted on by this acid than coke,—a circumstance which would prepare us for expecting that instead of a greater ratio of carbonic acid to carbonic oxide being present in the gases of a charcoal furnace there should be *less*. Many years ago, however, I proved that previous ignition rendered both coke and charcoal less susceptible of being attacked by hot carbonic acid; and here again my observations have recently been confirmed by those of M. Åkerman.

On passing a stream of carbonic acid over charcoal and coke separately at a good red heat, the issuing gases, according to this authority, contained, with charcoal, 13 per cent. by volume of carbonic oxide, with Durham coke 2·5 per cent. When, however, both had been previously ignited, there was practically very little difference between the two; the issuing gases contained from 1 to 1½ per cent. of carbonic oxide, indicating that very little action had taken place between the fuel and carbonic acid.

Now it is not impossible that charcoal, which has its resisting powers brought up to an equality with coke in the manner just described, may even greatly surpass coke in resistance to carbonic acid when both are exposed to the more intense heat of a blast furnace, and when the previous ignition therefore takes place at a much higher temperature.

So much, at any rate, is certain, that in the coke furnaces which I have examined, a mere trace of carbonic acid is found in the gases at a third of the height from the throat. Further, it must be observed that, having regard to all the circumstances, such as the power with which Cleveland stone retains it oxygen, the amount of resistance offered by Durham coke to the action of carbonic acid, and the temperature of the upper part of the furnace, a position of equilibrium is arrived at when, in a furnace of 48 feet, about 33 per cent. of all the carbonic acid, whether introduced as such into the furnace or generated by chemical action, has disappeared, or about 20 per cent. in one of 80 feet. The position of equilibrium referred to consists in there being in the case of the 48-feet furnace about 25 volumes of carbonic acid for every 100 of carbonic oxide, and about 45 in that of an 80-feet furnace.

Very different are the conditions which obtain in a charcoal furnace. This is apparent in the comparison already given between the Wrbna furnace and a coke furnace of 6000 cubic feet smelting Cleveland ore. From the information communicated to me, I have calculated, as nearly as I can, the weights of carbonic acid per 20 units of iron existing in the gases at various depths of the Wrbna furnace, which is about 37½ feet in height. These are as follow :—

	a. Escaping Gases.	*b.* 18 feet from Throat.	*c.* 25½ feet.	*d.* 28 feet.	*e.* 32 feet.	*f.* 34½ feet.
Units of carbonic acid in gases	15·42	14·76	14·79	13·39	13·29	3·20
„ carbonic oxide „	17·18	19·25	18·14	19·01	20·02	26·33
„ total oxygen „	21·03	21·75	21·12	20·60	21·11	17·38

Having regard to the oxygen contained in the material, as given in the analysis in M. Friderici's paper, and its capability to generate carbonic acid, it would appear that there is a disappearance of fully as much of this acid from the gases as in the case of a 48-feet furnace working on Cleveland stone with Durham coke, viz., about 33 per cent. Instead, however, of the carbonic acid being confined to 25 vols. (or even 45 vols., as in the 80-feet furnace) to 100 of carbonic oxide, it is found in the ratio of 57 to 100.

There is another striking difference between the behaviour of a furnace working with charcoal and one working with coke. While with coke nothing but a mere trace of carbonic acid is found in the gases at a distance of one-third the height of the furnace from the top, with charcoal there is nearly as much of this gas found at a depth of two-thirds, *i.e.*, 25½ feet from the throat, as appears in the escaping gases.

By far the largest quantity of the carbonic acid found in the gases of any blast furnace is due to the reduction of the ore. Now, I have proved by experiment that there are very great differences in the time required for separating oxygen from iron in different kinds of ore, but of all ores the spathose variety, used in the Styrian furnaces, is the most easily reducible. This fact would imply that deoxidation in these charcoal works should be more speedily accomplished than it is in a coke furnace in Cleveland, the ore of which latter district I have found to be about the most refractory of all ores I have examined.

This rapidity of reduction actually takes place in the Styrian furnaces; for although by far the greater portion of the oxygen is not separated until the ore reaches a point at a distance from the throat and close to the tuyeres, it must be remembered that, owing to the diminutive size of the furnace, this zone is reached in a very short time. Between *e*, *d*, *f*, in the table given—a height of only 6½ feet—almost the entire process of reduction is effected; for above *e*, up to the point of final escape, there is practically no increase in the amount of oxygen contained in the gases.

This view of the process of reduction is confirmed, to some extent, by a very instructive experiment of Ritter von Tunner's more than twenty-two years ago. He found that the first signs of reduction did not appear until the ore had reached a depth of 17 feet in the furnace; but at a similar level, in a coke furnace of 48 feet, this operation is entirely completed. This depth, however, in the charcoal furnace is reached in one hour, whereas in the coke furnace the ore does not arrive at the same point until after the lapse of about twelve hours. Thus the zone of reduction, in the case of charcoal, is greatly lowered in point of position, and the gases above it are so largely charged with carbonic acid as to be unable to deoxidise any of the freshly introduced ore through which they are passing.

In three or four hours the mineral reaches *e* and *d*, while the temperature is so high that reduction is extremely rapid, and where it would, in a coke furnace, be accompanied by the conversion of the carbonic acid into carbonic oxide, causing thereby a great loss of heat. It is, however, inferred that the position of static equilibrium, as affected by temperature and the proneness of carbonic acid to be resolved into carbonic oxide, is maintained by the previous ignition of the charcoal, which is thus rendered inert, comparatively speaking, in its action on the oxygen of the carbonic acid.

Allusion has already been made in this communication to the existence of cyanogen compounds in the blast furnace. The occurrence of these substances has been the subject of frequent inquiry at the works under my control.

I will give, in a few words, the results of some experiments bearing on this question, setting forth the extent to which alkaline cyanides were found in the gases of a furnace smelting Cleveland ironstone with coke.

Quantity of potassium and sodium, in combination with carbonic acid, oxygen, or cyanogen, found in one cubic metre of the gases of a furnace of 17,500 *cubic feet,* 80 *feet in height, ascertained upon six consecutive days at a point eight feet above the tuyeres.*

Potassium and sodium, grammes,	46·69	30·17	33·15	21·09	31·65	11·83,	**average**	29·11
Cyanogen present, . „	19·00	12·93	17·32	11·34	20·61	9·16	„	15·06

There is no doubt that as the gases ascend, more or less loaded with this alkaline vapour, a considerable portion of the latter is condensed by the cooler solids filling the interior of the furnace. The condensed matter is carried back to the inferior zones, and this gives rise to the accumulation in point of quantity perceptible in the gases at the lower levels of the furnace.

Besides this cause of disappearance of the cyanogen itself in the higher parts of the furnace, it would seem that some reaction takes place during the ascent of the gases, because the relation between the alkali metals and the cyanogen suffers a material change. Thus, on the six days upon which the specimens above mentioned were taken, the escaping gases were found to contain :—

Potassium and sodium, grammes,	11·20	15·30	8·68	5·89	4·29,	**average**	9·07
Cyanogen, ... „	4·00	6·60	3·57	2·91	1·79	„	3·77

The figures in these two examples indicate that 65 per cent. of the enumerated substances have disappeared from the gases between the two points of observation; and that while cyanogen in the first series bore a relation of 61 to 100 of the potassium and sodium, in the second it existed only as 41 to 100 of these metals.

In the belief that cyanogen, from the carbon vapour it contains, must be a powerful deoxidising agent, the following experiments were tried. Different mixtures of cyanogen and carbonic acid were passed over oxide of iron at different temperatures. The results are contained in the subjoined table.

Mixture.		Duration of Experiment.	Temperature.	Exposed Oxide contained per 100 of total Fe present :—			
Vol. Cy.	Vol. CO_2.			Fe as Metal.	Fe as Oxide.	O with Fe.	Carbon Deposited.
1	6	2¾ hrs.	698° C.	56·3	43·7	9·10	28·50
1	6	3·1 ,,	bright red	22·7	77·3	17·4	13·8
1	15	2½ ,,	806° C.	6·5	93·4	32·20	1·30
1	30	3 ,,	775	0·9	99·0	33·82	2·52
1	15	2·8 ,,	bright red	none	100·0	28·90	·52

By experiment it was found that carbonic oxide and carbonic acid in equal volumes, far from being able to reduce perfectly an ore of iron, actually converted metallic iron, at a red heat, into protoxide of iron. The same mixture, when passed over iron ore, produced at various temperatures no deposited carbon.

From what has preceded, we may infer that free cyanogen, at all events, is, as might be expected, a very much more powerful reducing agent than carbonic oxide; the carbon of which latter, from the composition of the gas, has its avidity for oxygen already partially satisfied.

Notwithstanding the energy with which cyanogen compounds are able to rob iron ores of their oxygen, I am not prepared to suggest that they necessarily play an important part in the reducing zone of the blast furnace. In charcoal furnaces the excess of alkali may probably be productive of a larger quantity of cyanides than in furnaces using coke; but even then it may be doubted whether the process, taken as a whole, is materially affected by their presence.

I have already compared the constitution, so to speak, of the heat coefficients usefully employed in the charcoal furnaces described by M. Friderici, and in a Cleveland furnace using coke.

In the paper by Professor Ritter von Tunner already referred to, the blast was only heated to 200° C. (392° F.); but in his later experiments of 1871 the temperature had been raised to 400° C. (752 F.) In M. Friderici's paper the blast is quoted as having been heated to 300° and 450° C. in the two furnaces, while the Cleveland furnace was blown with air at 485° C. (905° F.)

In my comparative statement just alluded to, I calculated that the heat actually absorbed in the furnace was, per unit of fuel consumed, as follows:—

	Charcoal Furnace 2.	Charcoal Furnace 3.	Cleveland Furnace.
	Calories.	Calories.	Calories.
Combustion of carbon	3609	3726	3653
Contained in blast	277	393	534
	3886	4119	4187
Less carried off in gases	222	281	509
Useful coefficient	3664	3838	3678

By raising the blast by means of brick stoves to temperatures from 700° to above 800° C., the following coefficients per unit of coke have been obtained:—

Height of furnace (feet)	76	90
Capacity of furnace	20,642	35,016
Weekly make, tons per 1000 cubic feet	24	13
Coke per ton	22·3	19·69
Temperature of blast C.	780°	819°
Temperature of escaping gases C.	412°	222°
	Calories.	Calories.
Combustion of carbon	3442	3551
Contained in blast	747	793
	4189	4344
Less carried off in gases	464	189
Useful coefficient	3725	4155

An important item in the evolution of heat by the fuel is the extent to which the carbon is burnt to the state of carbonic acid. There is no doubt that in this respect the charcoal furnaces greatly surpass any coke furnaces I have had an opportunity of examining. I annex a synopsis of the relations of carbon in the two conditions of oxidation, carbonic acid being taken as unity:—

	Charcoal. Furnace 2.	Charcoal. Furnace 3.	Cleveland.	Cleveland.	Cleveland.	Cleveland.	Cleveland.
Blast° C.	300°	485°	485°	522°	718°	780°	819°
CO	1	1	1	1	1	1	1
CO .	1·72	1·49	2·28	2·09	2·53	2·89	2·28

It needs no figures to prove that, provided the gas is equally saturated with oxygen, an elevation of temperature in the blast must be attended with an economy in the fuel consumed. But my own inquiries have led me to infer that, in furnaces of moderate size, receiving their blast at the high temperatures supplied by firebrick stoves, the gases have not proved generally as rich in carbonic acid as those fed with air at more moderate temperatures: whether from some difficulty connected with the conduct of furnaces under 25,000 cubic feet of capacity, or from some other cause, I am unable to say. As a consequence of this state of things, and in spite of so much more heat being imparted through the blast, according to my experience, there has not been any very great economy in the use of superheated air—always, be it remembered, comparing furnaces in good working order.

These observations apply to the smelting of Cleveland ironstone; but I have recently examined the results obtained in smelting hematite ores at four different works for the production of Bessemer iron, with the following results:—

	A.	B.	C.	D.
Height of furnaces, feet . . .	60	60	70	70
Stoves, metal or firebrick . .	Firebrick	Firebrick	Metal	½M ½FB
Coke, per ton	20·56	20·60	20·33	20·35

In some cases, no doubt, the results may be affected by differences in the quality of the minerals; but in the case D. I have separated the consumption of coke with the two descriptions of stoves, the same kind of minerals being used at all the furnaces. The results were:—

From metal stoves	20·54	
,, ,,	20·55	average 20·54 cwts. per ton.
,, firebrick stoves	19·97	
,, ,,	20·37	,, 20·17 do.

It may be, as would appear to be the case from a recent paper by Mr. Charles Cochrane, that superheated air requires a much larger furnace in order to realise the full benefit it is capable of affording. According to his figures, Cleveland iron is being smelted with something under 19 cwts. of coke, which is about 1½ cwt. less than I have met with under the most favourable circumstances. In this instance, however, per 1000 cubic feet capacity, the produce was only half that of furnaces driven with air at about 560° C. (1040° F.)

The heat developed for each unit of coke consumed at this furnace, 90 feet high with a capacity of 35,000 cubic feet, estimated on analysis of the gases at the throat, was, as just shown, 4344 calories, of which 4155 were usefully employed. This figure is undoubtedly one of high excellence, and is, in point of fact, the best I have met with in my experience with British furnaces.

There is but one other point to which I would ask your attention, viz., the great make of many furnaces using charcoal as their fuel. The usual produce of a coke furnace smelting Cleveland stone is about 30 tons of grey iron per 1000 cubic feet of capacity per week. The Luxembourg furnaces, using ore of the same geological position as those of Cleveland, run as much as 50 tons of white iron per 1000 cubic-feet of capacity, and from 50 to 55 tons is about the rate of working on English or Spanish hematite. It will be observed, however, that in the two Vordernberg charcoal furnaces we have a make of 73 and 93½ tons of white iron per week per 1000 cubic feet of capacity; and I have seen in America charcoal furnaces running 100 tons of grey metal per 1000 cubic feet.

It is clear that the facility with which an ore is acted on by the reducing gas in the furnace must necessarily affect the rapidity with which the furnace can be driven. By actual experiment I ascertained that at a temperature of 410° C. (770° F.), calcined Cleveland stone, when exposed to carbonic oxide, lost, in a given time, about 20 per cent of its combined oxygen, while Lancashire ore parted with 2½ times this quantity. Under such circumstances it is not surprising that charcoal furnaces using rich hematites should make much more iron than coke furnaces using clay ironstone. As a rule, however, up to a recent date the make per 1000 cubic feet was notably larger in charcoal furnaces than in those using coke, even when smelting the same class of ore. But I have recently learnt that the furnaces at the Edgar-Thomson Works near Pittsburg, 80 feet high, with a capacity of 15,000 to 16,000 cubic feet, are producing weekly fully 100 tons of coke pig per 1000 cubic feet, working on rich Bessemer ore.

There is no question whatever that driving furnaces at any such rate leads to their rapid destruction, so that three years is a pretty long life for one which is turning out so large a quantity; whereas a furnace making a third of this produce, even from the poorer Cleveland ore, lasts three or four times as long.

Now, when it is remembered that the cost of blowing-engines, hot-air apparatus, &c.—indeed, almost every expense attending the cost of manufacturing iron except the mere furnace itself—bears a direct proportion to the quantity of iron produced, and therefore is not diminished by an increase in the rate of production, it seems doubtful whether there is any saving in these extraordinary rates of production, which necessarily entail blowing out, and standing three months for repairs, in every third, instead of in every twelfth year.

DISCUSSION.

Professor Ritter v. TUNNER remarked that there was a great difference in the consumption of charcoal in producing white and grey pig iron. In Styria, they knew by experience that when they made grey iron for the Bessemer process, they required, on an average, 15 per cent. more charcoal than they did in producing white pig. The gases of the blast furnaces working with charcoal generally contained far more carbonic acid than blast furnaces where coke was the fuel employed. The considerations which the paper contained relative to the iron industry of Styria and Carinthia were of a general character; but he recommended the members to read the special monographs which had been prepared for them by the managers of the various works in Styria relative to the conditions under which they were accustomed to produce iron. For example, those monographs supplied an answer to the question, what may be the quantity of charcoal required for the production of 100 lbs. of pig iron at the blast furnaces of Vordernberg? It was shown that at blast furnace No. 18, which was the oldest and smallest furnace in the district, it was 83½ kilos. of charcoal, whereas at blast furnace No. 14, which was a new furnace, 13·27 metres in height, 2·212 metres width of bosh, and working with 200°–250° R. blast pressure, it was 70·1 kilos. of charcoal per 100 kilos. of pig iron. Again, at the blast furnace of Trofaiach—one of the newest and largest furnaces in the district, with a height of nearly 16 metres, a diameter at hearth of 1·58 metres, a bosh of 2·844 metres, and a blast pressure of 340° C.—the consumption of charcoal was 65 kilos. per 100 kilos. of pig iron. He believed that 65 to 70 lbs. of charcoal per 100 lbs. of pig iron was as good a result as they could expect, but sometimes the consumption got down as low as 63 lbs., although only for a short time. He should be glad to further explain these matters on the occasion of the excursion to the Vordernberg Valley, where a large number of charcoal blast furnaces were to be seen.*

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* A detailed description of the blast furnaces and the conditions of iron-smelting at the Vordernberg furnaces will be found at p. 618 of the present volume.

Mr. W. WHITWELL said he hesitated going into the numerous calculations in Mr. Bell's paper, knowing that they could not be disposed of in a few minutes' conversation. He was sure they all looked forward with very great interest to their visit to the charcoal districts. So far as America was concerned, from what he had heard from his agents, it seemed they were making something like 60 tons of iron per day from charcoal furnaces 53 feet high by 12 feet in diameter. It might be advantageous for the Americans to turn out large quantities, as their profits in good times were exceptionally great, so that they could drive their furnaces at double the speed of any they had in Europe, and then they could stop them for three or four months for repairs. Their practice in England, however, had been to adopt the system which was most economical, both with regard to the wear and tear of the furnace, and the consumption of fuel in the furnace. They all knew the speed of driving which best suited a particular furnace, as well as the temperature of the blast; and generally there was a limit of economy in the working of every individual furnace, which they wished to arrive at. With regard to the comparative make of pig iron in America and England, alluded to by Mr. Bell, he could not avoid saying how much pleasure he had had in observing the practice in Austria in that respect. He did not know that they had much better practice in England than he had seen at Witkowitz, where he found 100 tons were got from a blast furnace in twenty-four hours. They had two furnaces doing as much as that, and were blowing in another furnace that week, which they expected to do still more. With the material and the fuel they had in Moravia, that was an admirable result. As regarded the Whitwell firebrick stoves, he hesitated speaking about them, as he happened to be the executor of his brother, the late Thomas Whitwell, who was so much beloved by all who knew him. He might, however, say that he had carried out his brother's patent in Germany, France, Austria, and Hungary, and also in America; and his firebrick system of heating was undoubtedly one possessing very great advantages. It was, indeed, useful whether the heat was required to be of a medium or of a high temperature. There were three special systems in use for the purpose of heating the blast. He would not compare them in the slightest degree, but it was sufficient to say that it was advantageous for blast furnaces, large or small, to have a high temperature of blast, and they could only obtain that with the firebrick stoves. He did not dispute in the slightest degree what had fallen from Mr. Bell with reference to the cost of large outputs; but for large outputs great heat and great provision for blowing and heating power were absolutely necessary. In order to compare the statistics given by Mr. Bell, they must know all the particulars about the furnaces, including the elements of ore, of fuel, of flux, of pressure, and of temperature; and until they had exactly similar and parallel circumstances, they could not compare the results. They all knew how curious and sometimes how contradictory was the working of the blast furnace; but given the same circumstances, they could always compare them approximately. He had no doubt that the statistics which Mr. Bell had put before them were correct, and he deserved on that as on many previous occasions their most cordial thanks for furnishing them with a paper which would bear perusal again and again.

Mr. JAMES KITSON (who was in the chair) said it was satisfactory to those who had to employ the highest quality of material in their manufactures, and who required charcoal iron, and found it of so much service in the manufacture of high qualities of wrought iron, to hear that such pig iron was made with so low a consumption of fuel as 12 cwts.; and it was of great importance to those manufacturing the higher qualities of steel from the open-hearth furnace to see that there was still a possibility of a continuous supply of Swedish or other charcoal iron at a reasonable price. This led him to make the observation that in all those discussions they saw that there was room for each description of material that was manufactured; and that in the Iron and Steel Institute there was no question of enmity — of one material pushing out another,—but facilities of production and the growth of the world still afforded a field and a demand for all their products. The manner in which Mr. Bell had put the question of heat units, and their relation to the description of material treated, showed that it could be demonstrated that certain descriptions of mineral required certain quantities of heat to work them; thus the cost of reduction could be ascertained by reasoning instead of practical experiments. A more striking example of the benefits conferred by their Society could not in his opinion be afforded. Mr. Bell had laid the Institute and the manufacturers of iron throughout the world under great obligations by his early papers, which added lustre to their Proceedings; and he ventured to think that this paper and the discussions which would arise on it, would equally contribute to their service and their fame. He was sure they would accord to Mr. Bell a hearty vote of thanks for the excellent paper he had read to them.

Mr. I. LOWTHIAN BELL acknowledged most gratefully the kind terms in which the Chairman had alluded to his labours in connection with a subject to which he had no doubt paid great attention, and in which he felt much interest. In that respect he resembled his friend Mr. von Tunner, for the Professor had told him two days ago that the study of this branch of metallurgy had so much attraction for him that, if he were to begin life again, he would devote it to the study of iron.

The following paper was then read :—

ON THE SUCCESSFUL ROLLING OF STEEL INGOTS WITH THEIR OWN INITIAL HEAT BY MEANS OF THE SOAKING PIT PROCESS.

By JOHN GJERS, Middlesbrough.

When Sir Henry Bessemer, in 1856, made public his great invention, and announced to the world that he was able to produce malleable steel from cast iron without the expenditure of any fuel except that which already existed in the fluid metal imparted to it in the blast furnace, his statement was received with doubt and surprise. If he at that time had been able to add that it was also possible to roll such steel into a finished bar with no further expenditure of fuel, then undoubtedly the surprise would have been still greater.

Even this, however, has come to pass; and the author of this paper is now pleased to be able to inform this meeting that it is not only possible, but that it is extremely easy and practicable, by the means to be described, to roll a steel ingot into, say, a bloom, a rail, or other finished article with its own initial heat, without the aid of the hitherto universally adopted heating furnace.

It is well understood that in the fluid steel poured into the mould there is a larger store of heat than is required for the purpose of rolling or hammering. Not only is there the mere apparent high temperature of fluid steel, but there is the store of latent heat in this fluid metal which is given out when solidification takes place.

It has, no doubt, suggested itself to many that this heat of the ingot ought to be utilised, and, as a matter of fact, there have been, at various times and in different places, attempts made to do so; but hitherto all such attempts have proved failures, and a kind of settled conviction has been established in the steel trade that the theory could not possibly be carried out in practice.

The difficulty arose from the fact that a steel ingot when newly stripped is far too hot in the interior for the purpose of rolling, and if it be kept long enough for the interior to become in a fit state, then the exterior gets far too cold to enable it to be rolled successfully. It has been attempted to overcome this difficulty by putting the hot ingots under shields or hoods, lined with non-heat-conducting material, and to bury them in non-heat-conducting material in a pulverised state, for the purpose of retaining and equalising the heat; but all these attempts have proved futile in practice, and the fact remains, that the universal practice in steelworks at the present day all over the world is to employ a heating furnace of some description requiring fuel.

The author introduced his new mode of treating ingots at the Darlington Steel and Iron Co.'s Works in Darlington early in June this year, and they are now blooming the whole of their make, about 125 tons a shift, or about 300 ingots every twelve hours, by such means.

The machinery at Darlington is not adapted for rolling off in one heat; nevertheless they have rolled off direct from the ingot treated in the "soaking pits" a considerable number of double-head rails; and the experience so gained proves conclusively that with proper machinery there will be no difficulty in doing so regularly. The quality of the rails so rolled off has been everything that could be desired; and as many of the defects in rails originate in the heating furnace, the author ventures to predict that even in this respect the new process will stand the test.

Many eminently practical men have witnessed the operation at Darlington, and they one and all have expressed their great surprise at the result, and at the simple and original means by which it is accomplished.

The process is in course of adoption in several works, both in England and abroad, and the author hopes that by the time this paper is being read, there may be some who will from personal experience be able to testify to the practicability and economy of the process, which is carried out in the manner now to be described.

A number of upright pits (the number, say, of the ingots in a cast) are built in a mass of brickwork sunk in the ground below the level of the floor, such pits in cross-section being made slightly larger than that of the ingot, just enough to allow for any fins at the bottom, and somewhat deeper than the longest ingot likely to be used. In practice the cross-section of the pit is made about 3 inches larger than the large end of the ingot, and the top of the ingot may be anything from 6 inches to 18 inches below the top of the pit. These pits are commanded by an ingot crane, by preference so placed in relation to the blooming mill that the crane also commands the live rollers of the mill.

Each pit is covered with a separate lid at the floor level, and after having been well dried and brought to a red heat by the insertion of hot ingots, they are ready for operation.

As soon as the ingots are stripped (and they should be stripped as early as practicable), they are transferred one by one, and placed separately by means of the crane into these previously heated pits (which the author calls "soaking pits"), and forthwith covered over with the lid, which practically excludes the air. In these pits, thus covered, the ingots are allowed to stand and soak; that is, the excessive molten heat of the interior, and any additional heat rendered sensible during complete solidification, but which was latent at the time of placing the ingots into the pit, becomes uniformly distributed, or nearly so, throughout the metallic mass. No, or comparatively little, heat being able to escape, as the ingot is surrounded by brick walls as hot as itself, it follows that the surface heat of the ingot is greatly increased; and after the space of from twenty to thirty minutes, according to circumstances, the ingot is lifted out of the pit apparently much hotter than it went in, and is now swung round to the rolls, by means of the crane, in a perfect state of heat for rolling, with this additional advantage to the mill over an ingot heated in an ordinary furnace from a comparatively cold, that it is always certain to be at least as hot in the centre as it is on the surface.

Every ingot, when cast, contains within itself a considerably larger store of heat than is necessary for the rolling operation. Some of this heat is, of course, lost by passing into the mould, some is lost by radiation before the ingot enters into the soaking pit, and some is lost after it enters, by being conducted away by the brickwork; but in the ordinary course of working, when there is no undue loss of time in transferring the ingots, after allowing for this loss, there remains a surplus, which goes into the brickwork of the soaking pits, so that this surplus of heat from successive ingots tends continually to keep the pits at the intense heat of the ingot itself. Thus, if occasionally it happens that inadvertently an ingot is delayed so long on its way to the pit as to arrive there somewhat short of heat, its temperature will be raised by heat from the walls of the pit itself; the refractory mass wherein the pit is formed, in fact, acting as an accumulator of heat, giving and taking heat as is required to carry on the operation in a continuous and practical manner.

During the soaking operation, a quantity of gas exudes from the ingot and fills the pit, thus entirely excluding atmospheric air from entering; this is seen escaping round the lid, and when the lid is removed combustion takes place.

It will be seen by analyses given hereafter that this gas is entirely composed of hydrogen, nitrogen, and carbonic oxide, so that the ingots soak in a perfectly non-oxidising medium. Hence loss of steel by oxidation does not take place, and consequently the great loss of yield which always occurs in the ordinary heating furnace is entirely obviated.

The author does not think it necessary to dilate upon the economical advantages of his process, as they are apparent to every practical man connected with the manufacture of steel.

The operation of steelmaking on a large scale will by this process be very much simplified. It will help to dispense with a large number of men, some of them highly paid, directly and indirectly connected with the heating department; it will do away with costly heating furnaces and gas generators, and their costly maintenance; it will save all the coal used in heating; and what is perhaps of still more importance, it will save the loss in yield of steel, while there will be no more steel spoiled by overheating in the furnaces.

The process has been in operation too short a time to give precise and reliable figures, but it is hoped that by the next meeting of the Institute these will be forthcoming from various quarters.

Referring to the drawings (diagrams), fig. 1 shows the sectional elevation, and fig. 2 plan of a set of eight soaking pits (marked A). These pits are built in a mass of brickwork B, on a concrete foundation C; the ingots D standing upright in the pits. The pits are lined with firebrick lumps, 6 in. thick, forming an independent lining E, which at any time can be readily renewed. F is a cast iron plate, made to take in four pits, and dropped loosely within the large plate G, which surrounds the pits. H is the cover, with a firebrick lining; and I is a false cover of firebrick, one inch smaller than the cross section of the pit, put in to rest on the top of the ingot. This false cover need not necessarily be used, but is useful to keep the extreme top of the ingot extra hot. J is the bottom of the pit, composed of broken brick and silver sand, forming a good hard bottom at any desired level.

Fig. 3 shows outline plan of two sets of soaking pits KK, eight each, placed under a 25-feet sweep crane L. This crane, if a good one, could handle any ordinary make-up to 2000 tons per week, and ought to have hydraulic racking-out and swinging-round gear. This crane places the ingots into the pits, and, when they are ready, picks them out, and swings them round to blooming mill M. With such a crane, four men and a boy at the handles are able to pass the whole of that make through the pits. The author recommends two sets of pits as shown, although one set of eight pits is quite able to deal with any ordinary output from one Bessemer pit.

In case of an extraordinarily large output, the author recommends a second crane N, for the purpose of placing the ingots in the pits only, the crane L being entirely used for picking the ingots out and swinging them round to the live rollers of the mill. The relative position of the cranes, soaking pits, and blooming mill may of course be variously arranged according to circumstances, and the soaking pits may be arranged in single or more rows, or concentrically with the crane at pleasure.

Fig. 4 shows outline on plan and elevation of a Bessemer plant, conveniently arranged for working on the soaking pit system. AA are the converters, with a transfer crane B. C is the casting pit with its crane D. EE are the two ingot cranes. F is a loading crane which transfers the ingots from the ingot cranes to the soaking pits KK, commanded by the crane L, which transfers the prepared ingots to the mill M, as before described.

Mr. Stead, the well-known metallurgical chemist, of Middlesbrough, has investigated the heat phenomena and the composition of the gases in the soaking pits, and I have pleasure in giving his report, which is as follows:—

I.—ON THE RELATIVE PROPORTIONS OF HEAT IN FLUID STEEL AND STEEL HEATED AT A SUITABLE TEMPERATURE FOR ROLLING.

JOHN GJERS, Esq.

DEAR SIR,—At your request we have, with the assistance of your son, Mr. L. Gjers, made two comparative experiments at the Darlington Steelworks to ascertain what proportion of heat is contained in fluid steel over and above what is required for heating the ingots to the temperature suitable for rolling.

In the first experiment the heat in the fluid steel was estimated.

In the second, the ingot from the first experiment was heated in a mill furnace to the full bright heat necessary for ingots when rolling directly into rails, and this was treated in the same way as the fluid steel, excepting that the mould was not put into the calorimeter.

The results, although perhaps not giving the actual heat units in the steel, may yet fairly be considered to give a relative idea of the proportion.

The calorimeter consisted of a cylindrical vessel of lined iron, capable of containing fifteen gallons of water, enclosed in a second vessel, in diameter about eight inches greater than the first, and about four inches deeper. The space between was packed with dry cotton waste.

The interior vessel, closed at one end and open at the other, was provided with a tightly fitting non-conducting plug, consisting of a bag filled with dry cotton waste.

At the bottom of this vessel were placed two firebricks to support the hot steel ingot.

Water was then added, the quantity and temperature being most carefully recorded.

This somewhat crude apparatus, containing water considerably below the atmospheric temperature, when allowed to stand for above two hours in the Bessemer shop, was not sensibly affected, the temperature of the water remaining stationary, and when at the end of an experiment (when the water had a temperature of 47° C.) the vessel was allowed to stand for twenty minutes, it only cooled down to 46° C., a loss of 1° C.

The mould for securing the metal or steel was cubical in form, and was made in two halves, and these were secured in position by an iron ring. The cavity in the interior was a four-inch cube, and the thickness of the walls or sides two inches.

A passage one inch in diameter communicated with the inside of the mould.

In order to prevent the fluid steel coming into contact with the exterior of the mould, a large wide-mouthed funnel, lined with loam, was fixed into the opening at the top. When everything was ready, fluid steel from the Bessemer ladle was conducted from the funnel to the mould; and as soon as it was filled, the funnel was removed, a little sand thrown into the git, and the mould containing the steel plunged into the calorimeter, and there allowed to remain till the water ceased to increase in temperature.

This required a period of twenty minutes.

In order to expedite the cooling of the steel, the ring was slipped off the mould, and the water allowed to come in contact with the steel ingot.

After the maximum temperature was obtained, the water was allowed to stand for twenty minutes, to ascertain approximately the loss which must have occurred during the twenty minutes when the water was absorbing heat from the ingot mould and steel.

The loss sustained by the heated water on standing, theoretically would be slightly greater than the original loss; but as it only amounted to 1° C., I have not made any allowance for the difference in conditions.

The second experiment was made as before described, by heating the ingot from the first experiment, and cooling in the calorimeter.

After making corrections for the heat remaining in the steel ingot, in the ingot mould, and in the bricks, it was found that for every 100 units in the heated steel there are 154 in fluid steel.

Heated steel	100
Fluid steel	154

It is necessary to state that the steel ingot was heated to as high a temperature as it was capable of bearing without being burnt.

II.—ON THE GASES EVOLVED FROM STEEL INGOTS WHEN INTRODUCED INTO THE GJERS HEAT-ADJUSTING PITS.

JOHN GJERS, Esq.

DEAR SIR,—On July 11, 1882, samples of gas were drawn from your heat-adjusting pits at Darlington, and these were carefully analysed in our laboratory by Dr. Salvin Pattinson, with the following results, viz.:—

	No. 1.	No. 2.
	Per Cent. by Volume.	Per Cent. by Volume.
Nitrogen	62·92	69·65
Hydrogen	25·16	18·62
Carbonic oxide	7·95	6·90
Carbonic acid	3·97	4·83
Oxygen	nil	nil
	100·00	100·00

It is impossible to tell exactly what proportion of the nitrogen present is due to the air originally present in the pits. It is clear, however, that a very large proportion must have been derived from that source. The carbonic acid in all probability has been produced by the combustion of carbonic oxide originally evolved from the steel, the oxygen having been supplied by the air in the chamber.

By calculation we find that after deduction of this oxygen and accompanying nitrogen, the gases would have the following composition:—

	No. 1.	No. 2.
	Per Cent. by Volume.	Per Cent. by Volume.
Nitrogen	59·91	66·63
Hydrogen	27·21	20·47
Carbonic oxide	12·89	12·90
	100·00	100·00

The proportion of hydrogen burnt by air leaving nitrogen it is impossible to calculate. There must, however, still be a very large amount.

The following analysis represents the composition of the gas evolved from fluid steel, the sample having been taken from the top of a closed ingot mould when it was being filled with fluid steel from the bottom :

Hydrogen	82·5	per cent.
Carbonic oxide	12·5	,,
Carbonic acid	nil	
Nitrogen	5·0	,,
	100·0	

It is possible that a small proportion of the hydrogen might have been derived from the moisture in the slightly damp runner bricks; but there can be no doubt that the bulk of it passed out of the steel.

This analysis is introduced here as useful for comparison with the analysis of the gases evolved from solid steel.

The composition of the gases remaining in the pits after the removal of the ingots was as follows :—

Nitrogen	83·15	per cent.
Hydrogen	5·82	,,
Carbonic oxide	0·85	,,
Carbonic acid	3.39	,,
Oxygen	6·79	,,
	100·00	

The presence of these highly reducing gases, carbonic oxide and hydrogen, surrounding the hot steel ingots, must have a very important influence in protecting them from oxidation, and is a very important feature in the improved process.—We are, dear sir, yours truly,

PATTINSON & STEAD.

DISCUSSION.

The **Chairman** said that he had received two or three communications from gentlemen who were not present in reference to papers read. It was not, perhaps, convenient that communications of this character should be received at their meetings, and if gentlemen had anything to say on the papers, it would be better that they should be present to make them themselves. The first communication was from Mr. Stead, who had written to him corroborating generally the account given by Mr. Gjers in his paper on the use of the so-called "soaking pit;" and the second was a telegram from Mr. Alexander Wilson, in which he called attention to the patenting some years ago of a process said to be similar to that of Mr. Gjers. Mr. Bell would only observe, if all that was said of the process as described by Mr. Gjers was correct (and of his good faith there could be no doubt), there was between his mode and that of Mr. Wilson a very important difference. Mr. Wilson said that he attached no importance whatever to the invention, from which he inferred that it had, in Mr. Wilson's opinion, no value; but this particular invention was brought before them on account of its possessing a great value.

Mr. **Snelus** said he had great pleasure in bearing his testimony to the value of Mr. Gjers' discovery. He called it a discovery, because many of them might be aware, as he himself was, that Mr. Wilson certainly did patent a plan of trying to keep the heat in the ingots by covering the ingots with charcoal; but that was a crude plan, which did not succeed, and amounted to nothing; whereas Mr. Gjers' process was a great success. Mr. Snelus was now carrying out the process at West Cumberland. He had been placed in a peculiar position by having a strike of furnace-men just at the time that Mr. Gjers had got his process to work; and being invited to see it, he was so convinced of its value and so pleased with its results, that he went back to West Cumberland and put up some soaking pits, and started work at once. Unfortunately he did not then know the importance of lining the soaking pits with substantial blocks. They should not use small bricks, but sound, heavy blocks, because the mere mechanical attrition of putting the ingots in and out so often would knock the small bricks away. But that had nothing to do with the process. Notwithstanding this drawback in starting, they worked on, fought their heaters, and gained their point. In a week or two they got some special blocks, 9 inches deep, 18 inches thick, and mitred at the angles, as shown on Mr. Gjers' diagram. They started those pits last Monday week, and he had just received a report that they had heated over 1500 tons of ingots in the pits last week. Their total output was a little over 1800 tons of rails in one mill, of which over 1500 went through the soaking pits, and not into the furnace at all. Last Friday night they had put through the ten holes with the crane 204 ingots, weighing about 1800 lbs. each, equalling nearly 170 tons of steel. That was passed through the cogging rolls, and cogged in the same way as the steel from the furnaces. Therefore, to say that Mr. Gjers' process was not of much value was incorrect, for it was of very great value indeed. He was sorry that the process was too young to allow of his giving further details, but he might say that they usually employed six first heating furnaces at West Cumberland; while with this process last week they only used two, and really did not want more than one to reheat ingots that became cold. They would agree that in this there must be a large saving. They had two other furnaces for using up a stock of cold ingots that had accumulated during the strike; and last week they increased their output some three or four hundred tons, owing to having the pits at work. The saving was very great, though he had not ascertained it rightly yet; but he soon found that ingots going through the ordinary heating furnace gave a very much larger proportion of short rails than those that went through the pits; and this was enough to show that there was much less waste in the pits than in the furnace. Of course men had to learn how to use the pits, just as they had to learn how to work a furnace, and it was quite as possible to spoil an ingot in a pit as in a furnace; but he was quite sure that there was less chance of spoiling it in a pit than in the furnace. The men must become accustomed to the work. Their Bessemer pits at West Cumberland were at some distance from the cogging. They had to carry each ingot separately, throw it down on the ground, lift it up with the crane at the soaking pit, drop it into the pit, and keep it there for twenty minutes or half an hour. It was then taken out and put into a special bogey, where the ingot stood upright, being entered at the end of the bogey. The man then ran it a short distance, and toppled it over on to the rolls. Unfortunately they could not at present carry the plan out to the best advantage, but their crude way of doing it answered well enough, and he repeated that last week they cogged from the pits 1500 tons of ingots, and on Friday night 170 tons, or at the rate of nearly 2000 tons per week. He had no doubt they would do better. If they did not get 2000 tons next week, and if 90 per cent. did not go through the pits, he should be very much disappointed.

Mr. KITSON asked how the rails could be spoilt?

Mr. SNELUS replied that the ingots could be spoilt by taking them out too soon, when the fluid steel would be out at the end. Again, the pits might be carelessly worked, and an ingot might be made too hot on one side and too cold on the other. But these were little things; and although the plan had been working so short a time, his manager was thoroughly satisfied with it. He was a very conservative man, and at first it was very difficult to convince him that the process was all right, but his face was all aglow when he told him (Mr. Snelus) that he had got the best shift out with these pits he had ever had, and without any trouble at all. They had the ordinary Bessemer apparatus, and they cast the ingots at the pits attached to the Bessemer converters. They had some little trouble in getting all the ingots out of the moulds and to the pits quickly, but that would soon be got over.

Mr. WINDSOR RICHARDS observed that he could not speak from his own experience of the working of these ingots, but he had been to the Darlington Steelworks on two occasions, and was surprised at the results obtained. He saw a great number of ingots taken direct from the Bessemer and placed in these so-called soaking pits. The ingots were cogged and rolled off. He did not follow Mr. Snelus in his statement as to rolling off. Did he take the ingot and roll it into a rail direct from the soaking pit, or did he take the ingot and roll it into a bloom, and then reheat the bloom and roll it into a rail? Was there one heating? At a great many steelworks rails were being rolled after *one* heating only. What was now being tried for was the rolling of rails in several lengths without heating by fuel at all.

Mr. T. HUGH BELL remarked that, as Mr. Gjers had told them, they worked under very great disadvantages at Darlington owing to the weakness of their machinery, but still they had been able to roll directly off. The ingot was taken from the casting-house and put into the soaking pit, and it was rolled directly into a rail. He did not know whether Mr. Snelus did that; but if their Darlington mill was what it ought to be, they would have no difficulty in doing so. It would give the Darlington Steel Company great pleasure to receive any gentlemen who might be desirous of seeing Mr. Gjers' plan, and of making themselves thoroughly acquainted with the advantages it possessed.

Mr. SNELUS explained that at West Cumberland they had not adopted the plan of rolling off at one heat, as the arrangements of their mill did not admit of it. The ingot at the cogging rolls would have to be passed over the finishing to get to the roughing rolls; and their machinery was so arranged that they could not very well roll off. He had no doubt that it was possible to roll the ingots into rails without putting them into a furnace at all. They were unable to do so at West Cumberland, not from the fault of the process, but from the disposition of the machinery. They hoped to follow the plan Mr. Gjers had designed, and he had no doubt that rails would be made without either first or second heating. They only dispensed at present with first heating, and that was worth from 2s. to 2s. 6d. per ton; and if they could do without second heating, there would be a saving of about 4s. per ton,—that is, including the saving in waste as well as in fuel, labour, &c.

Mr. WHITWELL had very much pleasure in confirming what had fallen from the author of the paper. He went one day to Darlington, where he arrived unexpectedly about seven o'clock, and he spent the time from that till nine in watching the process. The rails were being rolled in one length (they were 84 lbs. section, double-headed, for the North-Eastern Railway Company), and he saw about 80 per cent. of these put into the pits and rolled off. The ingots in use were naturally rather small for this process; and he was led to the opinion that had they been double the size they would have been more easily dealt with, and would have retained the heat better. He did not see any flanged rails rolled. The process seemed remarkably simple, and the saving in waste was evident. Under all the circumstances, had the machinery been sufficiently strong for the rolling of rails in four lengths or in three or four lengths, he had no doubt whatever that he should have been able to see the rolling of flange rails, as he did see the one length of the 84-lb. double-headed rails. He heartily congratulated Mr. Gjers on this interesting adjunct of steel-making, and thought its use would effect an economy that would benefit the world.

Mr. JEREMIAH HEAD considered that after what had been said it was scarcely necessary to speak of the advantages of Mr. Gjers' invention. Still, the members of the Iron and Steel Institute were very naturally and properly sceptical of anything new, and therefore it was only due to those who read papers on new inventions that members who had actually seen them in operation should give expression to their impressions. He was glad to be able entirely to confirm the previous speakers as to what was going on at the Darlington Steelworks. He also had an opportunity of seeing ingots stripped and put into soaking pits, when they appeared on the outside to be of a very dull red heat only. After being there for half an hour, they were taken out, bloomed, and without additional heat finished off into North-Eastern double-headed rails. The heat of the finished rail, after the last pass, seemed to be much greater than the heat of the ingot when put into the pit; and there was no doubt whatever as to the substantial success of the process. He noticed that the workmen seemed always to put a piece of coal into the soaking pit when an ingot was taken out. He was not at all clear as to the object of this—whether it was of any use, or merely a workman's idea. It seemed certain that no combustion could go on inside the pit, because there was no air present; and inasmuch as non-oxidising gases came off from the ingot itself, there was no necessity for using other means to obtain a neutral atmosphere. It seemed to him that Mr. Gjers' principle might be developed and extended in some other directions. Other districts were no doubt in a similar position to Cleveland, in that blast furnaces were usually carried on by one set of firms, and the rolling and finishing of iron by another—the rolling mills being at a distance from the blast furnaces. In case the blast furnace firms wished to put up steel-making plant by the basic process, for instance, it might become necessary for them to send ingots to the rolling mills to be finished off. Why should not the soaking pits be placed on wheels in the form of a large bogey, and the half-hour necessary to soak might also be utilised in travelling? Supposing the journey took half an hour, the ingots would arrive at the rolling mills in right condition to pass through the cogging mill. He was rather surprised to hear of the considerable thickness in the brick lining required for the soaking pits. It was known that a very high temperature might be on one side of a brick three inches thick, when the other side might be quite cool. In fact, a small crucible furnace might be sufficiently hot to melt steel inside, and on the outside they might lay their hands. But the reason for the extra thickness was perhaps the constant succession of hot ingots, and it might also be rendered necessary by attrition in bringing them out.

The CHAIRMAN: Mr. Snelus stated that to be the only reason for having thick bricks.

MR. HEAD (resuming) observed that, according to his reckoning, the pits which were in operation at Darlington were heating about ten tons per pit per shift; but it appeared that Mr. Snelus was getting a greater tonnage, due probably to his charging heavier ingots. He should like to point out that it was of the very greatest possible practical advantage at the present time to have a process like this, which did away with the necessity for the workmen called heaters, inasmuch as that particular class of workmen were extremely difficult to get. They were scarce in England, and he learnt from Mr. Kupelwieser that it was the same in all parts of the Continent; and therefore the invention came at an opportune moment to meet a serious difficulty.

Mr. A. Cooper said that, through the kindness of Mr. Gjers, he was allowed to see the process for utilising the initial heat of ingots in its first stage. This consisted in making a series of six square pits under a small crane in the Bessemer shop, the Bessemer shop being some 200 feet from the cogging mill. On the occasion of his visit, he saw upwards of a dozen ingots put into these pits, and they were allowed to remain from fifteen to twenty minutes. They were afterwards bogeyed to the cogging mill, and rolled off into blooms in a satisfactory manner. Under these unfavourable circumstances, he thought they might fairly assume that there would be no difficulty in rolling straight off into rails with quicker and more powerful machinery. At a more recent visit, about a fortnight since, he saw them placing the series of pits close to the cogging mills, and arranging them so that a crane should receive the ingots from the bogey, put them into the pits, and afterwards take the ingots from the pits to the rolls. He did not see any ingots rolled direct into rails, but he was informed by the manager of the works that a few days previously they had been rolling them. He thought that all who had seen the process in operation would allow that, notwithstanding the principle had been known, and many attempts had been made to carry it into effect, Mr. Gjers' plan was about as simple and as cheap a method as could be devised.

Mr. Gjers, in reply, said it was to be understood that this process could be applied to blooming at any existing Bessemer works, but that all such works could not do the rolling off into finished rails unless they had sufficiently good machinery. Mr. Head had stated that the workmen sometimes put a small piece of coal in the furnace. Well, it did happen that the workmen did put a small piece of coal in the pit, and for this reason, that sometimes the pits actually got inconveniently hot, and in that case a piece of coal was introduced for the purpose of reducing the heat.

The **Chairman**: That is quite true.

Mr. **Gjers** could assure gentlemen that there was no fear of insufficient heat, for it required the best firebricks to stand the temperature in the pits. Every ingot had surplus heat, which must go to and accumulate in the brickwork; and the pits continually got additional heat. He himself felt fully persuaded from the experience already gained that direct rolling off from the soaking pits would become general.

A hearty vote of thanks was passed to Mr. Gjers for his valuable paper.

The following paper was then read:—

ON THE CHEMICAL COMPOSITION AND TESTING OF STEEL RAILS.

BY G. J. SNELUS, F.C.S., F.R.S.M., WORKINGTON.

THE author has been induced to bring this subject under the notice of the Institute with a view of starting a profitable discussion upon these important points, and not because he can lay claim to any originality in the treatment of the subject, or because he has any discoveries to record. Most of the members of the Institute will have seen the valuable papers upon the subject by Dr. Dudley of Altoona, chemist to the Pennsylvania Railway Company, but probably very few have carefully studied these, and the elaborate and thoughtful remarks which were made upon them by American metallurgists at the meetings of their Institute of Mining Engineers. For the benefit of those who are not acquainted with them, the writer may state that he refers to the paper on the "Chemical Composition and Physical Properties of Steel Rails," by Dr. Charles B. Dudley, read at the Lake George meeting, October 1878, and the paper on "The Wearing Capacity of Steel Rails in Relation to their Chemical Composition and Physical Properties," by the same author, read at Philadelphia in 1881. These papers and the discussions are so valuable that it would be well if they could be incorporated bodily into our own Transactions, for the benefit of many of our younger members, who may not otherwise be able to consult them.

Whatever may be thought about Dr. Dudley's *deductions*, there cannot be two opinions as to the thoroughness and general reliability of his investigations. No similar research has been attempted on this side of the Atlantic. Our worthy President, Mr. Smith, did, however, precede Dr. Dudley in investigating the relation between the chemical composition, physical properties, and wear of steel rails, and embodied his results in a paper read before the Institution of Civil Engineers, session 1874–75. This was followed in 1876 by a paper by R. Price Williams on the "Permanent Way of Railways," in which also many important facts were brought to light. Mr. C. P. Sandberg has also presented to the American Institute of Mining Engineers a thoroughly practical paper on "Rail specifications and rail inspection in Europe."

But notwithstanding these valuable papers and the discussions to which they have given rise, it may fairly be said that the proper composition for a steel rail is far from settled yet.

Mr. J. T. Smith and Dr. Dudley both came to the conclusion, as the result of their experiments, that the softer steel rails, that is, those with low tensile strain and great elongation, gave the best wear. Unfortunately, those tested by Mr. Smith were only examined for carbon. The percentage of this element was shown to increase with the hardness of the rail. Dr. Dudley carried his analysis farther, and examined altogether 89 rails most carefully for carbon, silicon, phosphorus, and manganese. He has also attempted to fix the relative hardening properties of each of these elements, and assumes that 1 part phosphorus, 2 silicon, 3 carbon, and 5 manganese produce the same hardening effect upon steel, and he sums up the combined effect of all these elements in what he terms *phosphorus units.* These phosphorus units he arrives at by taking the analysis of the steel and adding together the phosphorus, one-half the silicon, one-third the carbon, and one-fifth the manganese, expressed in hundredths per cent.

Now it is well known that the effect of any one element is intimately dependent upon the proportion of others that may be present in the steel. Thus, steel with the large percentage of silicon shown in the following analysis—

Iron	98·784
Carbon under	·100
Silicon	·833
Sulphur	·043
Phosphorus	·075
Manganese	·216

was found to bend well and be very tough. Indeed it is well known that the steel used for castings may contain very large quantities of silicon and comparatively high carbon, and yet be very tough so long as it is well annealed. But annealing is not practicable for rails, and all steelmakers are aware that if the silicon rises to over ·2 per cent. the carbon must be kept down to about ·35 per cent., or the rail will ordinarily be brittle.

One of the rails tested by Dr. Dudley showed the following remarkable analysis:—

Carbon	·483
Silicon	·480
Phosphorus	·035
Manganese	·782

Notwithstanding this, it was tough, and one of the best wearing rails. It will be noted, however, that the phosphorus is *very low*, and it had in all probability been practically annealed by cooling very slowly on the hot bank.

Dr. Dudley, as the result of his investigations, arrived at the following ideal composition for the best wearing rails:—

Carbon	·334
Silicon	·060
Phosphorus	·077
Manganese	·491

This result he arrived at by taking the average composition of 32 slow-wearing rails, and he suggested that this should be modified to—

Carbon	·300
Silicon	·040
Phosphorus	·100
Manganese	·35

because American manufacturers cannot work to so low a phosphorus as that given in the previous analysis. In his first investigation he found that the average of 12 rails which did not break showed carbon ·287. In those which broke the average of carbon was ·366. Similarly in twelve unbroken rails the phosphorus averaged ·077, and in the broken rails phosphorus averaged ·132, and in every case in which the phosphorus was above ·12 the rail either broke or crushed. Again, in the unbroken rails he found manganese average ·369; in the broken, ·521; but he found scarcely any difference in the silicon, that in the unbroken rails being ·044, and in the broken ·047.

From his investigations of the 64 rails in regard to *wear*, Dr. Dudley concluded that the 32 slower-wearing rails, as compared with the 32 faster-wearing rails, yielded the following results :—

Number of Line.	Number of Rails in Average.	Description of Averages.	Loss per Million Tons.	Grade.	Degree of Curve.	Torsion Tests.			
						Height of Diagram.	Length of Diagram.	Elastic Limit.	Area of Diagram.
17	32	All conditions, slower wearing.	·0506	...	...	3·00	13·59	1·16	34·13
18	32	All conditions, faster wearing.	·1028	...	...	3·26	11·08	1·27	30·35

Tensile Tests.						Shearing Tests.		Bending Tests.		Chemical Analysis.					Density.
Unannealed.			Annealed.												
Tensile Strength.	Elastic Limit.	Elongation.	Tensile Strength.	Elastic Limit.	Elongation.	Shearing Stress.	Depression.	Maximum Load.	Deflection.	Carbon.	Phosphorus.	Silicon.	Manganese.	Phosphorus Units.	
[*] 75·125	36·031	17·1	73·219	33·281	18·5	57·537	·0933	2878	160°	·334	·077	·060	·491	31·3	·78211
80·188	38·125	14·2	77·188	36·594	13·8	61·922	·0856	3222	133°	·390	·106	·047	·647	38·9	·78165

Mr. Smith concluded as the result of his investigations that the best material for rails should contain ·3 per cent. carbon, and have a tensile strain of from 31 to 33 tons per square inch.

Notwithstanding the apparently convincing proofs adduced by Mr. Smith and Dr. Dudley in favour of a soft steel for rails, there are plenty of advocates for harder material, and the North-Eastern Railway Company, after stating that Bessemer steel made in recent years has not been found to wear so well as that made earlier, specify that their rails shall contain ·45 to ·5 carbon. And well-known English engineers give the following composition for manufacturers to work to:—

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[*] The tensile tests, &c., are given in pounds per square inch.

“Carbon not less than ·3 or more than	·45
Silicon	·06
Phosphorus	·06
Sulphur	·06

There must be no other material present except manganese and iron.”

The writer, having made more than half a million tons of rails approximately to the composition just mentioned, can testify to the toughness of those so made, but he has had no opportunity of ascertaining the result of their wear; indeed he doubts much if any of them have yet worn out. While many contracts made under his supervision have guaranteed the rails for five years or more, no single rail has ever been returned as worn out during the guarantee, and very few indeed have either broken or crushed.

Dr. Dudley considers that wear is “a function of the amount of distortion by bending that a piece will bear,” and endeavours to explain it by an ingenious hypothesis which may be worth repeating. He says—“As to the second question, Is there any conception which helps us to understand why it is that the softer rails give the better wear? I will say that in view of our absence of knowledge as to exactly what quality or combination of qualities of steel wear is a function of, the answer to this question becomes difficult. Nevertheless we may possibly get a little help upon this point by devoting a few moments to the consideration of what takes place when steel suffers loss of metal by wear. What then is the condition of the surfaces involved in wear? What are the forces which act, and what are the strains produced?

“If I understand the matter correctly, no two surfaces ever have been made, or can be made, that are absolutely smooth. At the very best, the smoothest surfaces are made up of elevations and depressions, very minute, it is true, perhaps almost infinitesimal and entirely incapable of measurement, but nevertheless real elevations and depressions. When these elevations and depressions are tangible, we call the surface rough; when they are infinitesimal, we call it smooth. If, now, this reasoning is correct, the surface of the head of a rail, as well as that of the circumferences of the wheels above it, are made up of elevations and depressions, which, when the two surfaces are in contact, must more or less fit into one another. And it is this fitting-in of the minute elevations and depressions of the two surfaces that gives rise to friction. If the two surfaces were absolutely smooth, there would be no friction, and, consequently, no tractive power in the locomotives, nor would the wheels under the cars turn around. Friction of this kind we are accustomed to call rolling friction. In reality, then, a rail and the wheel which rolls above it may be regarded as a rack and pinion with infinitesimal teeth, lacking, of course, the element of regularity as to the position of the teeth which characterises a rack and pinion. So much for the surfaces involved in wear. Now what are the forces involved in wear, and what strains do they give rise to? If I understand the matter rightly, there are two kinds of friction which may occasion loss of metal by wear in the case of rails: first, rolling friction, which occurs when the wheels turn around and the trains move forward; and, second, sliding friction, which occurs when the wheels turn around in the same place, as in the case of slipping drivers, or when the wheels do not turn around and move along the track, as in the case of sliding wheels. It is probable, however, that by far the largest portion of the loss of the metal which rails suffer is due to rolling friction; it will therefore, perhaps, be sufficient for our purpose to consider this case only.

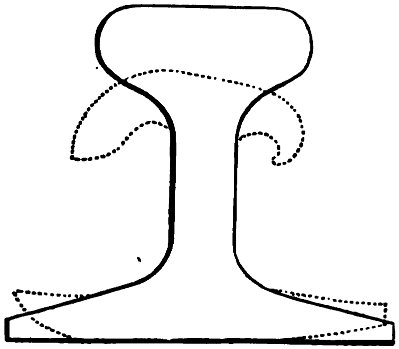
"The forces which act between the top of the head of the rail and the wheels in rolling friction may, it seems to me, be regarded as two in number. There is, first, a force acting directly downwards, due to the weight of the locomotives and cars. This force may be regarded as a vertical force acting perpendicularly to the head of the rail, and is in action both when the train is standing still and when it is in motion. Secondly, there is a force acting parallel to the head of the rail, due to the traction or impelling power of the locomotives. In the case of the driving-wheels, this force may be supposed to act in the direction opposite to that of the motion of the trains. In the case of all the other wheels, this force may be supposed to act in the direction of the movement of the trains, and it is antagonism to this force by the rail that causes all these wheels to turn around. In the case of the drivers, the amount of this force acting parallel to the head of the rail is sufficient to overcome the total train resistance; in other words, to cause the train to move. In the case of the other wheels of the train, acting individually, this force parallel to the head of the rail is small, being only that necessary to cause the wheels to turn around; in other words, to overcome journal friction. The force parallel to the head of the rail acts only when the train is in motion.

"In the case of rolling friction, there is, of course, no wear except when both these forces are acting at once. But when two forces are acting at the same time, their line of action must be regarded as in the direction of the resultant of the two forces. In the case we are considering, we have a vertical force and a horizontal force acting at the same time, and the resultant line of action must, of course, be a diagonal. In other words, in rolling friction, if the conceptions given above are correct, the line of action of the force which produces wear must be regarded as a diagonal to the line formed by the head of the rail. In the case of the driving-wheels, the diagonal is inclined towards the front end of the train, and in the case of the other wheels it is inclined toward the rear of the train.

"Returning for a moment to the conception previously mentioned, that the top of the head of the rail and the surface of the circumference of the wheel are a rack and pinion, with infinitesimal teeth, but without regularity in the teeth, let us see what kind of strain would be produced in these minute teeth by a force acting diagonally to the line of the head of the rail. I hardly see how we can avoid the conclusion that this strain would be a bending strain. In the case when the infinitesimal teeth of the wheel and rail did not fit into interstices, but struck against each other, in which case the ends of the teeth only would be involved in the strain, then surely the strain would be a bending one. And again, in the case in which the teeth mutually engaged each other as a rack and pinion so long as there was motion of the train, which is a necessary condition of rolling friction, it seems to me that the strain would still be that of bending.

"If we are right in regard to the nature of the surfaces involved in wear and the strains produced, wear is simply the breaking or pulling off of the infinitesimal teeth by the strains to which they are subjected. And here we see why it is that the softer rails give the better wear, for the harder the steel the more brittle it is, and the more brittle the steel the more readily will these infinitesimal teeth be broken off by the strains applied. On the other hand, the softer the steel the more readily will these infinitesimal teeth bend and flatten down under the strain without breaking off. Or, to make the statement general, if the nature of the steel is such that under the strains applied, whatever they may be, the teeth readily break off, which is characteristic of hard steel, the more rapid will be the wear. If, on the other hand, the nature of the steel is such that the teeth readily suffer distortion without rupture, bend and flatten down without breaking off, which is characteristic of soft steel, the slower will be the wear."

It is clear, from the experiments of Mr. Chanute, that with 14,000 lbs. weight and upwards on a locomotive driving-wheel the pressure exerted exceeds the elastic limit of the steel at the points where the wheel touches, and that therefore these minute projections, which we must admit exist upon the surface of every rail, will be permanently distorted by every revolution of the wheel, and ultimately break off. On the other hand, the diagrams of worn rails exhibited by Dr. Dudley show clearly that in many cases there is a remarkable flow of metal from one point to another. As a case in point, fig. 2 of Dudley's illustrations may be reproduced.



Now, whether more metal will be removed by the flow of a soft material, as shown above, or by the breaking off of minute surfaces by a grinding action, will depend upon many circumstances, and can only be determined by actual experiment for each set of circumstances.

It is quite a common thing at railway stations, where brakes are much used, to see flakes of steel fairly squeezed off the heads of the rails to the outer side, and gradually broken away. The same kind of wear must take place in a minor degree upon all portions of the line.

While, however, it is by no means a well-settled point whether hard or soft steel rails wear the best, there can be no doubt that hard steel rails are more liable to fracture, and therefore, on the whole, it is perhaps better for the manufacturer to err on the soft side. But Dr. Dudley's ideal composition for a rail is one which it would be difficult and expensive for the manufacturer to work to absolutely; besides which, there is no doubt whatever that it is not the composition which would produce the soundest ingots. The writer agrees with Mr. Jones of the Edgar-Thompson Works that "the first thing toward making a good serviceable steel rail is to make a sound ingot, free from porosity, sponginess, or honeycomb;" and this opinion is endorsed by Mr. E. Williams and many other authorities.

Now, is the composition laid down by Dr. Dudley likely to give a sound ingot? We think not, and that to get sound Bessemer steel, as ordinarily made, either more carbon, more silicon, or more manganese must be introduced. The question is, which of these elements can be increased with the greatest advantage? Probably the silicon, because it is well known that a very small extra amount of silicon will tend to produce solid steel; so that if the silicon be raised to ·1 or even ·15 per cent., the steel would be improved without being seriously hardened; and besides, Dr. Raymond has shown, by a remarkable mathematical formula deduced from Dr. Dudley's analysis, that within certain limits silicon does not increase the loss of metal by wear. Manganese may also be used with a like result, and probably in larger quantity, as any excess behaves like so much iron. This will explain why English manufacturers now use so large an excess of manganese with impunity. As, however, it is an expensive element, there is every reason to economise its consumption, compatible with making sound ingots. There appears, then, to be no reason why the manufacturer should be tied down to the narrow limits of ·04 silicon and ·35 per cent. manganese, even though it may be true that the soft steel wears best and produces least fractured or crushed rails. *There is, however, every reason for keeping the phosphorus low.* There can be very little doubt that this element, even in minute quantities, is highly dangerous, and the attempt to hide its dangerous qualities, as in the manufacture of the Terre-Noire phosphoric rails, has had a very poor success. The writer has, on more than one occasion, expressed his opinion that the small excess of phosphorus in English Bessemer over Swedish steel is the main reason for the inferiority of the former, and he cannot too strongly insist upon the advantages of the basic process in enabling us to remove the last traces of this noxious element. Really, we require in a steel rail many of the qualities which exist in good cutlery steel. Thus a good knife will retain a keen edge without being brittle on the one hand or doubling up on the other; and so we require steel for rails of such a quality that the teethlike projections, described by Dr. Dudley, shall neither break off nor be squeezed off.

We would say then that a railmaker should aim at the following composition for steel rails:—

Carbon, ·35 per cent.
Silicon, ·10 ,, ,,
Phosphorus, as low as possible, but not above ·075 per cent.
Manganese, ·75 per cent.

About ·1 should be allowed as a limit of variation in carbon and silicon, and ·25 for manganese. We would also say that a slight modification should be made in the values affixed to each element by Dr. Dudley in estimating their phosphorus units; and, after careful consideration, we think this factor should be determined by adding phosphorus + ⅓ carbon + ⅓ silicon + ⅛ manganese. Taking the formula just given, we should then have—

Carbon	·35 =	·116
Silicon	·10 =	·033
Phosphorus	·06 =	·060
Manganese	·75 =	·093
		·302

Or removing the decimal point two places, 30·2 as the phosphorus units in a good rail. Now, taking a rail with all the elements the same, but raising the carbon to an undoubtedly dangerous limit—say ·6 per cent.—we should raise the phosphorus units to 38·6. Similarly, taking carbon, phosphorus, and manganese constant, and raising the silicon to ·35, we should have 38·5 phosphorus units. Again, raising the phosphorus to ·15, we should get 39·2 phosphorus units; and lastly, raising the manganese to 1·5, we should have 39·6 units; while, if we take all the elements at the extreme limits allowed, we should get 41·2. The steel should, therefore, be fairly safe with about 35 phosphorus units on this scale. The American manufacturer will make a steel with more phosphorus, and the German maker with more silicon, and each must reduce the carbon in proportion, but at the expense of producing a worse steel. No doubt a steel with considerably more silicon and less carbon, as made in Germany, would stand tensile strains equally well, but it would give way in bending and concussive strains, while the more phosphoric steel would not stand either one or the other test as well as our English standard.

Great credit is due to Dr. Dudley and his assistants for the patient investigations which they have made, but it is perfectly clear that he has not succeeded in convincing all, or even a great portion of those interested, that soft steel is better on the whole than moderately hard metal. We agree with Mr. Sandberg that this question can only be satisfactorily settled by a number of railway companies each laying down, say, 1000 tons of soft rails on one side of the line and 1000 tons of hard rails on the other. To ensure regularity in all other respects (as far as possible), except that of chemical composition, these two sets should be made by the same manufacturer. This plan would be a comparatively simple one, and it would involve the testing of such a large number of samples, that an average might then be struck with safety, as individual exceptions would have very little effect upon the average; whereas even in Dr. Dudley's more extended series only *one* abnormal rail upsets the calculations in a most serious manner. There would be no difficulty in any railmaker preparing two such sets of rails; their average chemical composition, absolute weight, and many other properties, could be determined beforehand, and the only drawback would be that we should have to wait some years for the results. Meantime we must go on manufacturing by the present formula or any that may be ultimately proved to be better.

In laying down a chemical formula for the *manufacturer to work to*, the writer does not wish to assert that rails made according to this composition will be perfect, as he is aware that many other circumstances besides the mere chemical composition affect the quality of a steel rail. The hardening effect of wear pointed out by Mr. Smith is a phenomenon to which comparatively little attention has been given, but that it is a point of importance will be seen from the sample of a steel rail now before you. This is a portion of a steel rail made by the Mersey Steel Company and laid down on the way of the Caledonian Railway Company, where it has been in use on the main line in a cutting three-quarters of a mile from Buchanan Street Station, on a down gradient of 1 in 80, for over nine years, viz., from August 1872 to September 1881. It had lost about 21 lbs. per yard, and when taken up was tested by a falling weight of 1800 lbs., the fall gradually increasing from 3 inches to 3 feet, the 3-feet fall, at which the rail broke, being the eighth blow. The rail was placed on 3-feet bearings.

The rail shown has the following composition:—

Iron	98·911
Carbon	·450
Silicon	·037
Sulphur	·130
Phosphorus	·076
Manganese	·396
	100·000

which certainly does not indicate any special reason why it should be so very brittle; and the fact that it has been in hard service so many years would seem to prove that it was hardly so brittle originally, so that its present condition must be to some extent the result of the molecular change from constant vibration, to which Mr. Smith refers. It is curious that it is almost identical in phosphorus units with Dr. Dudley's theoretical good rail, as it gives 32·3 instead of 31·3.

The reduction of area in rolling, temperature at time of rolling, rate of cooling, and many other accidental circumstances, will affect the quality of steel rails; and therefore railway companies and railway engineers should not specify a hard and fast line for the manufacturer to work to, but be satisfied with testing the quality of the rail when made by a simple plan which will correspond in some degree to the work the rail is expected to perform. This brings us to the second part of the subject.

Testing Steel Rails.—The following methods of testing rails are at present in use or suggested:—1. By examination of the fracture; 2. by chemical analysis; 3. by a blow from a falling weight; 4. by bending under, or the lever test; 5. by taking the tensile strain, elongation, and contraction of area; 6. by the torsion test; 7. by the punching test, suggested by our President. Some engineers' specifications provide for only one of these tests, others for several; and at times engineers specify for a chemical composition and a physical test which are quite incompatible.

We will take these tests in order.

1. *Examination of the Fracture.*—There is no doubt that the fresh fracture of steel is a very accurate guide, in highly skilled hands, to its quality; but the test is entirely empirical, and so much depends upon the judgment of the individual, that it is not one which could be implicitly relied upon.

2. *Chemical Analysis.*—It has already been stated that chemical analysis should be used by the manufacturer as a guide to the production of the proper quality of steel, and that he should aim at a definite chemical composition as the most important means of producing the desired result. But it has also been conclusively shown that two rails differing widely in chemical composition may be equally good in use, and, at the same time, that rails having an apparently perfect chemical composition may yet be inferior from other causes. Under these circumstances it is evident that a moderately wide range should be allowed in chemical composition, and that rails should not be condemned on this head alone. At the same time, in cases of failure, it is always desirable to make an analysis, as this will *very often* point out the cause.

3. *The Falling-Weight Test.*—This is probably the simplest and best mode of testing rails, as it enables the inspector to make his tests rapidly upon the full section of the rail, and the

test, when reasonable, approximates in some measure to the effect produced upon the rail in actual use. It infallibly detects rails that are either too hard or too soft. But engineers almost invariably specify a test far in excess of anything the rail will ever be called upon to suffer in actual use, and this often leads to the rejection of rails that are really good. Further, it is the custom of some engineers to insist upon whole rails being tested, and others even go so far as to insist upon a full 30-feet rail being tested, refusing to test one that is, for instance, 27 feet long. This is surely a gross waste, for the quality of the steel can equally well be determined by testing the crop ends; and if this is done regularly, the test of an occasional short rail just to satisfy the engineer, who cannot be present during the whole process of manufacture, ought to be sufficient. Some engineers specify that as much as 2 per cent. of good rails must be subject to this wasteful process. With rails at £5 per ton only, this means a loss to the manufacturer of nearly 1s. per ton, exclusive of the cost of testing. This would mean to a works of moderate capacity, say making 100,000 tons rails per year, a loss of £5000 per annum. Manufacturers have to work very hard to effect this much saving in any *other* part of the process of railmaking. The falling-weight test; properly applied, is, however, in the opinion of the writer, the best that can be made. In the West Cumberland Works it is systematically applied to a large portion of the crop ends, say one from each blow on every shift, and it is also used to test the quality of the steel before it is sent into the mill.

A small ingot 2 inches square is cast during the running of the first ingot, and is taken while still hot to a tilt hammer, drawn down to ¾ inch square, allowed to cool in the open air, and when just cold placed under a falling weight and bent by one blow to an angle of 45 degrees, thus V. Unless the steel will stand this test the ingots are not sent into the mill, but placed on one side for further examination.

There is one difficulty in connection with the specification of the falling-weight test, and that is, that the test to be applied must vary with every section of rail; and the particular test which a rail will stand can only be determined by actual experiment. The deflection given by rails of a number of sections in common use, and by steel having approximately the composition mentioned in the former part of this paper, may be of service to some, and is recorded in the Appendix.

4. *Lever Test.*—This is a test which may reasonably be applied to finished rails within the limits of elasticity, but if extreme limits are applied up to the point of rupture, it should be on crop ends, so as not to waste good rails. The falling-weight test, however, properly applied, gives nearly the same information that can be obtained by extreme lever-tests; and therefore this test might, as before stated, be confined to weights within the elastic limit of the rail.

A table in the Appendix shows the results of the lever test upon a number of rail sections similar to those tested by the falling weight.

5. *Tests by Rupture.*—A good testing-machine will no doubt afford very valuable information regarding the quality of steel; but certain varieties of steel, as was abundantly proved in the case of the *Livadia's* plates, will give very good tensile strain, elongation, and contraction of area, and yet be very brittle. This fact is now becoming well known to those engaged in testing German steel, and therefore the testing-machine ought not to be relied upon as a means of testing steel rails, even if it were practicable to take a full section of a rail and pull it asunder. But when, to carry out this test, portions have to be cut from the rail, it becomes unreliable from another cause, viz., that metal from different parts of the rail will give different tensile tests. But the chief reason why this mode of testing is inapplicable to rails is that it is utterly impossible to make a fair number of tests within a reasonable time, and therefore the results could only be ascertained long after the rails ought to have been finished and delivered.

6. *The Torsion Test.*—Most of the remarks about tension tests apply to this also, and it is very rarely specified.

7. *The Punching Test, suggested by the President.*—This has never yet been applied in practice, and now that so many rails are drilled and not punched, it becomes inapplicable. A modification of this test, however, might very well be made, and appears to the writer to be both a simple and practical test, while it has the advantage of being scientific in its application, and, above all, capable of being applied to every rail. Most of

our mills are now rolling three-length rails, and therefore a single crop end would fairly represent three rails. If a small hydraulic punch were placed near the saw, a crop from each rail could be thrown into a bosh of running water, and, as cooled, these could be tested by placing them in the machine and noting the depth of the indentation caused by a *known pressure* of a cone-shaped punch. The rail crop should be placed head uppermost, so that the indent is always made upon this part. It might be preferable to cut off a section of 3 or 4 inches from the rail and use this instead of the crop. These samples could then be kept for a while for examination. No fixing would be needed, and the testing would easily keep pace with the rolling without any expensive superintendence, especially if the instrument be made *self-registering.* By making it *self-recording* also, a perfectly permanent record could be obtained of the relative hardness of every rail. By constructing the instrument so as to exhibit the depth of the indent on a dial, the attendant could instantly call the attention of the manager to any extreme cases of hard or soft rails, and thereby check the manufacture in time, and the test could easily be repeated without delay. Of course the crop ends would be hardened by cooling them in water, but this would be rather a gain than otherwise, as it would emphasise the characteristic of hardness or softness; and as they would all be hardened from nearly the same temperature, the effect would be a constant one. By using this test and then subjecting a single crop end from every blow to a set falling weight, very perfect records would be obtained, that would, in the author's opinion, obviate the necessity of any more elaborate tests.

It would be comparatively easy after making the pressure test to follow any doubtful rails, and mark them for subsequent examination by other methods.

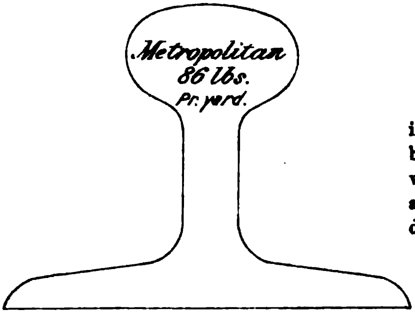
Appended will be found the methods of testing specified by all the leading companies in this kingdom, and many others; and if variety is charming, they have at least this merit. I also append reports from the engineers of several leading English railways regarding wear, &c., of their rails.

As stated in the commencement, the author's object in presenting this paper to the Institute is rather to initiate a discussion than to offer suggestions or to record facts.

TEST.					CHEMICAL COMPOSITION.			
n.	5th.	Weight in lbs.	Tec-Susn.	Bearings.	Carbon.	Silicon.	Phosphorus.	Sulphur.

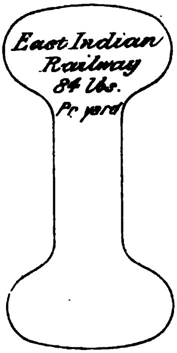
SCALE ⅓

APPENDIX.



MECHANICAL TEST.

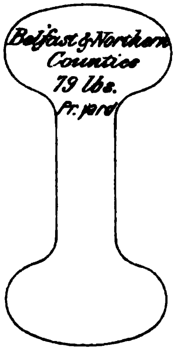
The rail to be placed flange downward on V bearings 5 ft. apart, and must bear a pressure midway between the bearings not less than 40,000 lbs. without deflecting more than 1 in., and must bear a maximum load of not less than 70,000 lbs., and deflect 9 in. in the centre without snapping.



MECHANICAL TEST.

Two rails to be placed on bearings 3 ft. 6 in. apart, and a weight of 33 tons will be suspended from each centre, and each deflection under the weight must not exceed ⅜ in. After being on half an hour the rail must not show any permanent set.

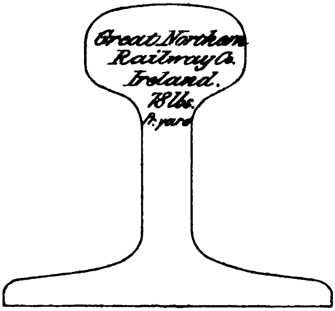
The same rail placed on bearings 3 ft. 6 in. apart as before, a ball weighing 1 ton to be dropped upon the centre from a height of 24 ft., and the rail must bear two such blows without breaking, and the permanent set must not exceed 2¼ in. with the first blow.



MECHANICAL TEST.

A rail placed upon bearings 3 ft. apart must bear a blow from a ball weighing 1 ton dropped from a height of 15 ft. without fracturing the rail, and on the same bearings the rail must sustain a dead weight of 26 tons without signs of fracturing.

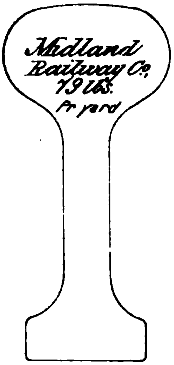
Scale ⅓



MECHANICAL TEST.

The rail to be capable of sustaining a tensile strain of not less than 30 tons to the square inch of sectional area.

The rail to be placed on bearings, and a ball weighing 18 cwt. to be raised 9 ft. and allowed to fall three times; the deflection must not exceed 3 in. And to bear 33 tons without permanent set, and a test of 35 tons without breaking upon bearings 3 ft. apart.

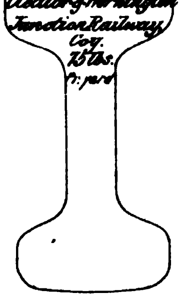


MECHANICAL TEST.

Each rail to be capable of sustaining a weight of 20 tons, applied frequently in the centre of the bearings, without injuring the elasticity or producing permanent set, and shall be capable of resisting without fracture three blows of a ram 20 cwt. falling a height of 12 ft. on the centre. The bearings to be as follows:—

For rails having section equal to 85 lbs. per yard, 4 ft. 9 in.

Rails of 70 lbs. per yard, 3 ft. 4 in.

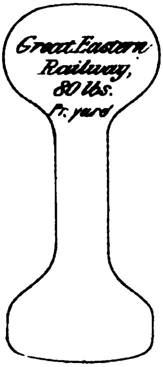


MECHANICAL TEST.

1st. The rail to be placed on bearings 3 ft. apart, and loaded with 24 tons on the centre. There must be no permanent deflection after the load has been on half an hour.

2d. On the same bearings the rail shall bear without breaking the impact of a weight of 1800 lbs. falling from a height of 6 ft.

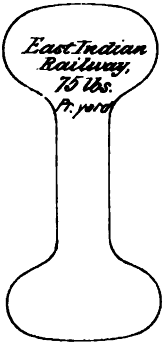
SCALE ⅓



MECHANICAL TEST.

A selection of two rails will be made from say 100 rails. Each of the selected rails, the "bullhead" uppermost, will then be placed on bearings 3 ft. 6 in. apart, and a weight of 18 tons will be suspended from the centre, and its deflection must not exceed ⅜ths of an inch after the weight has been on the rail for half an hour; and after the removal of the weight the permanent set must not exceed ⅛th of an inch. The next trial each rail, the "bullhead" uppermost, will be subjected to is as follows:—

Placed on bearings 3 ft. 6 in. apart, a ball weighing 1800 lbs. will be dropped upon each from a height of 8 ft., and the rail must bear two such blows without breaking, and without deflecting more than an inch. The jaws in which the rails are to be placed for testing to be of wrought iron, bedded in timber 12 in. square and 6 ft. long, laid on ballast 2 ft. thick on hard ground.



MECHANICAL TEST.

Dead and Live Weight Tests.

1st. The rail to be placed on bearings 3 ft. 6 in. apart, and equidistant from the centre of the rail. A weight of 28 tons will then be suspended from the centre of the rail. Its deflection must not exceed ⅜ths of an inch after the weight has been on the rail half an hour, and upon the removal of the load the rail must not show any permanent set whatever.

2d. The same rail being laid on bearings 3 ft. 6 in. apart as before, a ball of 1 ton will be dropped from a height of 18 ft., and the rail must bear two such blows without breaking, and the permanent set must not exceed 2½ in. with the first and a further 2½ in. with the second blow.

The tested rail will then be fractured, and must show a fine, close-grained, homogeneous surface.

The rails to be subjected to complete chemical analysis from time to time, and comply with the following conditions:—

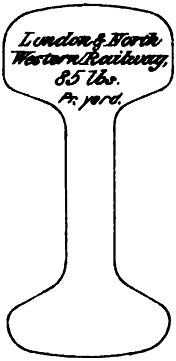
Carbon, not less than 3 per cent. or more than ·45 per cent.

Silicium, not more than ·06 per cent.

Phosphorus, not more than ·06 per cent.

Sulphur, not more than ·06 per bent.

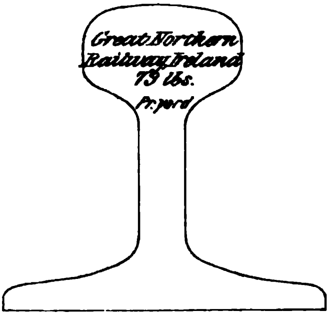
SCALE 1/3



MECHANICAL TEST.

The rail must stand without breaking a permanent deflection of 3 in. in a length of 3 ft. This deflection must be produced by one blow of a weight falling from a height of not less than 20 ft. upon the centre of a rail placed head uppermost upon two supports 3 ft. apart.

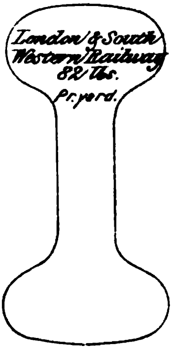
The pieces of rail tested need not exceed 3 ft. 6 in. in length.



MECHANICAL TEST.

A rail shall be placed on wrought iron bearings 3 ft. apart, when a ball or ram weighing 18 cwt. is to be raised 9 ft., and allowed to fall three times upon the centre of the rail between the points of support, when the deflection must not exceed 3 in. A rail shall be subjected to the further test of 23 tons dead weight applied in the centre without permanent set, and the test of 35 tons applied in the centre without breaking upon bearings of 3 ft. apart.

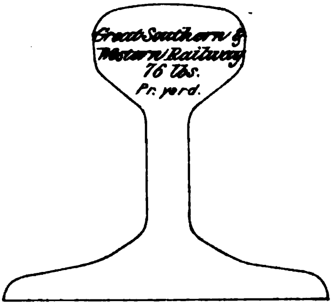
Pieces of rails shall also be taken and tested either in the full section, or cut down to certain reduced sizes and sections, so as to ascertain if the actual power of resistance is equal to a strain of 30 tons per square inch of sectional area, and the rails will be rejected if samples of them will not bear the above tests of falling weight, dead weight, and tensile strain.



MECHANICAL TEST.

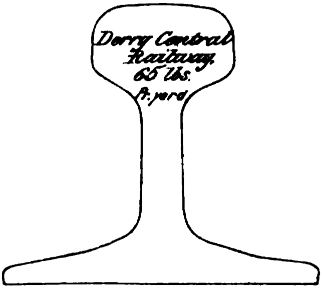
Two pieces of rail, each 4 ft., will be taken from each day's work, and placed on bearings 3 ft. 6 in. apart. A weight of 20 tons, and subsequently of 30 tons, will be placed on each of the pieces of rail at the centre between these bearings; and one piece of rail 4 ft. long will be placed on bearings 3 ft. apart, and a mass of 1 ton weight will fall upon the centre of it, through 20 ft.

SCALE 1/3



MECHANICAL TEST.

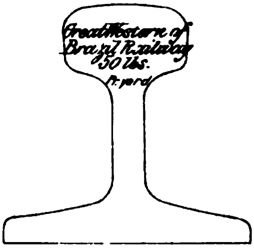
The rails shall be subject to any reasonable tests, in order to ascertain their strength and soundness, that the engineer or his deputy may require: and a rail may be placed on bearings 3 ft. apart, and a ball weighing 18 cwt. is to be raised 9 ft., and allowed to fall three times upon the rail between the points of support, when the deflection must not exceed 3 in., and the rails will be rejected if samples of them will not bear the test of 23 tons without permanent set, and a test of 35 tons without breaking, upon bearings 3 ft. apart.



MECHANICAL TEST.

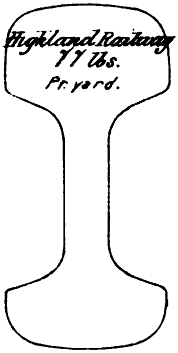
A piece to be cut from any part of any rail at the discretion of the engineer, and is to sustain a tensile strain before fracture of not less than 30 tons per sectional inch, with an extension of not less than 10 per cent. Any piece of rail supported at 3 ft. intervals, and tested by a falling weight over 10 ft., and such as to bend it 3 in. by one blow, shall not be fractured or cracked.

SCALE ⅓



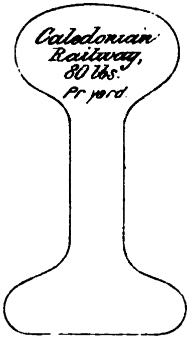
MECHANICAL TEST.

Rail to be placed on bearings 3 ft. apart, and a ram weighing 12 cwt. to be let fall twice upon it from a height of 15 ft., and the rail shall not exhibit any sign of fracture; to be then broken and a portion about 5 ft. put on bearings 3 ft. apart, 12 tons to be suspended, and deflection not to exceed ½ in., and to show no permanent set.



MECHANICAL TEST.

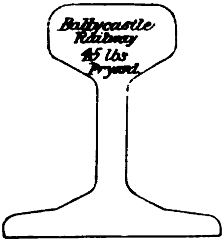
Rails must stand without breaking a permanent deflection of 3 in. in a length of 3 ft. Deflection must be produced by one blow of a weight falling 20 ft. upon the centre of a rail placed head uppermost upon two supports 3 ft. apart. It must also be sufficient to bear a weight by lever of 20 tons on 3½ ft. bearings without permanent deflection, and 36 tons without fracture.



MECHANICAL TEST.

Each rail shall bear a weight of 20 tons midway between bearings 3 ft. without permanent deflection and 35 tons without breaking, or more than 1½ in. deflection, on the same 3 ft. bearings. Also two strokes from a ball 1800 lbs. weight let fall from a height of 5 ft. without breaking, or more deflection than 1½ in.

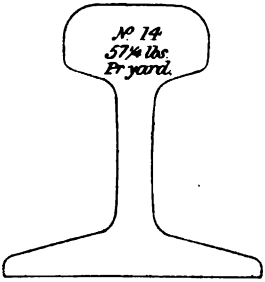
Scale ⅓



MECHANICAL TESTS.

1st Test.—A rail supported on firm bearings 3 ft. apart in the clear, and sustain without showing any signs of fracture one blow from an iron ball or monkey weighing 1200 lbs. dropped from a height of 12 ft.

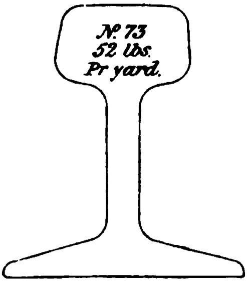
2d Test.—Placed on similar bearings, a rail shall sustain a weight of 12 tons placed in centre, and not more than $\frac{1}{16}$ of an inch of permanent set shall be found on removal of this load after it has been on half-an-hour.



MECHANICAL TESTS.

One rail out of every 100 tons. *a.* Rail placed on supports 3 ft. 8 in. apart will be loaded middle with weight of 15 tons; under such weight deflection is not to exceed $\frac{1}{8}$ in., and permanent set $\frac{1}{32}$ of an in. The rail to be further loaded to 28 tons, and must stand it without fracture. *b.* The rail to be broken in halves by falling weight (each half about 10 ft. long). One of the halves, placed on supports 3 ft. 8 in. apart, is to stand without fracture a blow from a ball 12 cwt. weight, falling height of 15 ft. Rail also submitted to successive blows from a ball weighing 3 cwt. from heights of 3, $4\frac{1}{2}$, 6, and 7 ft., the respective deflections are not to exceed $\frac{1}{8}$, $\frac{3}{8}$, $\frac{11}{16}$, and 1 in.

The steel used for rolling the rails is to contain about $\frac{1}{4}$ of one per cent. of carbon, not exceeding 0·3 and not under 0·25 per cent.



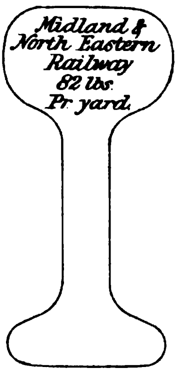
MECHANICAL TESTS.

Test by Weighing.—Rail placed on 2 supports distant 3 ft. 5 in., under action of load 12 tons during 5 minutes, must not show more than 4 mm. bend; on removal of load a bend of more than 1 mm.

Test of Break by Loading.—A rail having stood preceding test must support load of 1200 lbs. for 5 minutes without breaking.

Test by Blow.—Halves of a rail broken under preceding test are placed on same supports, and must resist 2 blows of weight of 20 and 30 lbs. falling upon middle of rail from height of 6·5 ft. Rail may bend under blow, but must not show any outward signs of deterioration. Length of halves for test must not be under 10 ft.

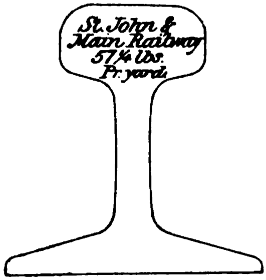
Scale ⅓



MECHANICAL TEST.

Each rail is to be capable of sustaining a weight of 20 tons, applied frequently in centre of the bearing, without injuring its elasticity, or producing a permanent set, and shall also be capable of resisting without fracture 3 blows of a ram 20 cwt. falling from a height of 12 ft. on the centre.

The bearings to be 4 ft. apart.

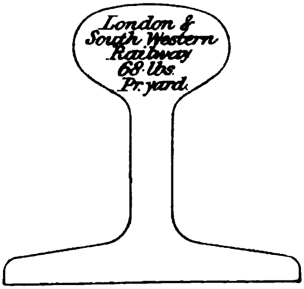


MECHANICAL TESTS.

1st. Each selected rail must carry 13 tons in the centre, between 3 ft. bearings, for 5 minutes without permanent set.

2d. Rails must carry in same position a load of 26 tons without breaking. After this flange of rail will be cut and rail broken. Fracture to show perfect welding, especially in the head.

3d. Each half of broken rail to be again placed on 3 ft. bearings, and to stand a blow from ball of 1 ton falling from a height of 15 ft. on the rail between the supports without showing any fracture. Bearings to be of cast iron fixed on oak frames, and supported on solid masonry 4 ft. deep.

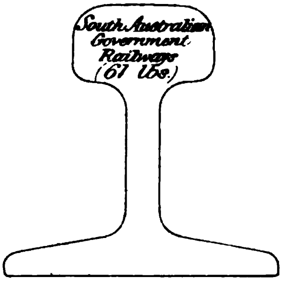


MECHANICAL TESTS.

Two pieces of rail 4 ft. long placed upon bearings 3 ft. 6 in. apart. A weight of 15 tons, and subsequently 25 tons, will be placed on each of the pieces of rail at the centre between these bearings.

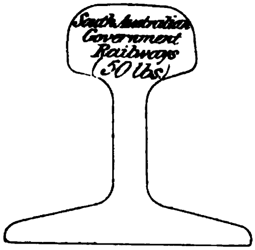
One piece of rail 4 ft. long will be placed on bearings 3 ft. apart, and a mass of iron 1 ton weight will fall upon centre of it through 10 ft.

Scale ⅓



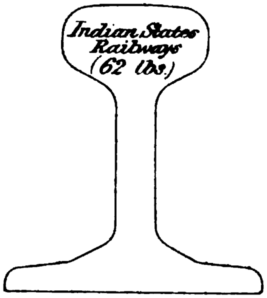
MECHANICAL TESTS.

A rail placed upon supports 3 ft. apart. A tupp weighing 10 cwt. shall be let fall upon it from the height of 10 to 16 ft. The rail to stand four blows of this kind without breaking. A dead weight of 15 tons shall be allowed to remain on the rail in same position for 10 minutes without producing permanent deflection.



MECHANICAL TESTS.

A rail placed upon supports 3 ft. apart. A tupp weighing 10 cwt. shall be let fall upon it from a height of 8 to 12 ft. The rail to stand 4 blows of this kind without breaking. A dead weight of 12 tons shall be allowed to remain on rail in same position for 10 minutes without producing permanent deflection.



MECHANICAL TESTS.

1st. A rail 30 ft. long placed on wrought iron bearings 3 ft. apart, equidistant from its ends. A weight of 15 tons will then be suspended from centre of the rail. Deflection not to exceed $\frac{1}{16}$ of an in. after weight has been on the rail half an hour.

2d. The same rail will be supported as before, and a cast iron monkey weighing 1 ton will be allowed to fall freely upon centre of rail from a height of 15 ft. The rail must bear 2 such blows without showing least sign of fracture.

3d. The rail when broken must show a fracture perfectly sound and homogeneous.

The rails on analysis must comply as under :—

Carbon, not less than ·3 per cent., must not be more than ·45 per cent.

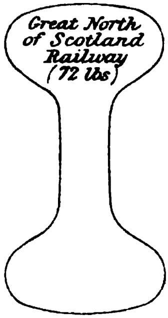
The quantity of silicium must not be more than ·06 per cent.

The quantity of phosphorus must not be more than ·06 per cent.

The quantity of sulphur must not be more than ·06 per cent.

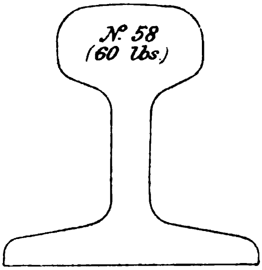
There must be no other materials present except manganese and iron.

Scale 1/3



MECHANICAL TESTS.

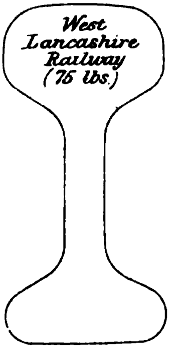
Each rail shall be sufficient to bear a weight of 15 tons without permanent deflection, and a weight of 30 tons for 3 minutes without fracture. No greater permanent deflection than 1¼ in., bear also 2 strokes from a ball 1500 lbs. weight, let fall from a height of 5 ft. without fracture, or greater permanent deflection than 1½ in.



MECHANICAL TESTS.

A portion of selected rails to be placed on supports 4 ft. apart, and must stand without fracture a blow from a ball of 10 cwt. falling from a height of 15 ft.

Another portion of the rail similarly supported shall be submitted to successive blows from a ball weighing 3 cwt. from a height of 3 ft., 4 ft., and 5 ft. The respective deflections not to exceed ⅛, ¼, and ½ in.



MECHANICAL TESTS.

1. From each day's make 2 pieces of rail 13 ft. long upon solid bearings of masonry or iron, 3 ft. 6 in. apart, dead load in centre 28 tons. Deflection after half an hour not to exceed ½ in., nor the permanent set ¼ in.

2. Two pieces of rail 13 ft. long from each day's make, solid bearings 3 ft. 6 in. apart, weight 1800 lbs., running in proper guides, and falling upon the centre of the rails—fall 20 ft.

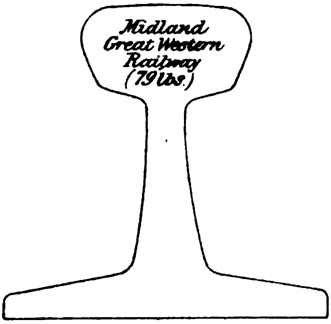
Rail to bear 2 blows without being cracked or fractured.

1st *Blow.*—Deflection not to exceed 4 in.

2d *Blow.*— ,, ,, ,, 7 in.

The rails when fractured to show a clean, close, and homogeneous fracture.

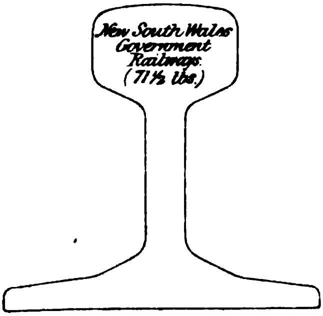
Scale ⅓



MECHANICAL TESTS.

1st Test.—A selection of 2 rails will be made say out of 100 rails. Each of the selected rails will then be placed in their usual position on bearings 3 ft. 6 in. apart, and a weight of 18 tons applied at centre between bearings. Deflection not to exceed ⅜ of an inch after weight has been applied for half an hour. After removal of weight the permanent set not to exceed ¼ of an inch.

2d Test.—Rails to be placed on bearings 3 ft. 6 in. apart. A ball weighing 18 cwt. will be dropped from height of 8 ft. Each rail must bear 2 such blows without breaking, and without deflecting more than 1 in.

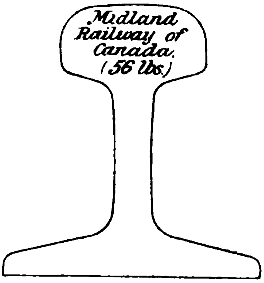


MECHANICAL TESTS.

Certain rails of each day's make shall be selected, and each rail tested shall have a portion 4 ft. 6 in. long cut off, this placed head upwards upon iron supports 3 ft. 6 in. clear. Rail to receive 3 blows from weight of 1 ton falling 6 ft. each time. Rail not to deflect more than 3 in., and without showing any signs of fracture. Then to be placed under steam hammer upon iron supports with head upwards, and shall be further bent by repeated blows to 8 in. out of a straight line in a length of 3 ft. 6 in., and must then exhibit no sign of fracture.

Rails also subjected to suspended load of 25 tons between 3 ft. 6 in. clear bearings, without permanent set exceeding $\frac{1}{16}$ in., and to any other reasonable tests the engineer may direct.

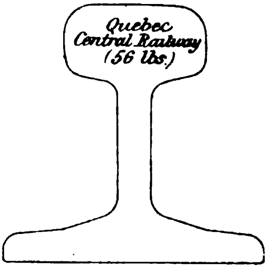
Scale ⅓



MECHANICAL TESTS.

A certain number of rails, not exceeding one per cent. of the whole, will be selected from each lot of the rails. Each of the selected rails must carry 13 tons in the centre between 3 ft. bearings for 5 minutes without permanent set. The rails must carry in same position a load of 26 tons without breaking; after this the flange will be cut and the rail broken.

Each half of broken rail again placed on 3 ft. bearings, and must stand a blow from a ball weighing 1 ton falling from height of 15 ft. on rail between supports without showing any fracture.



MECHANICAL TESTS.

1st Test.—Two pieces of rail 6 ft. long from each day's make, solid bearings of iron or masonry 3 ft. apart, dead load in centre 12 tons. Deflection after 10 minutes not to exceed ⅓ inch, nor the permanent set ⅓ of an in.

2d Test.—Similar piece of rail upon bearings as above. Weight 1800 lbs., and running in proper guides and falling upon centre of rail; fall 10 ft.

Rail to bear 3 blows without being cracked or fractured, thus—

1st blow, deflection not to exceed 3⅓ in.
2d ,, ,, ,, 6 ,,
3d ,, rail reversed, deflection to be reduced to 3 in.

Chemical proportions in the ingots shall conform as follows:—

Quantity of carbon to be from ·28 to ·45 per cent., but about ·35 per cent. preferred.

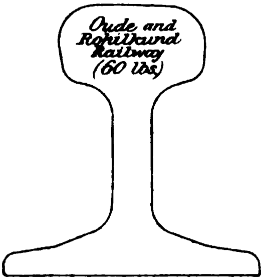
Quantity of silicon not to be more than ·06 per cent.

Quantity of phosphorus not to be more than ·07 per cent.

Quantity of sulphur not to be more than ·08 per cent.

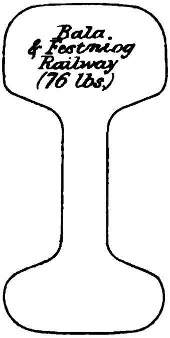
The only metals to be iron and manganese, with a proportion of copper not exceeding ·03 per cent.

Scale ⅓



MECHANICAL TESTS.

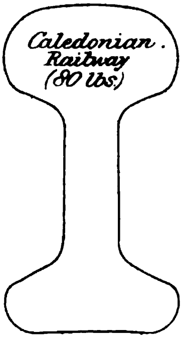
Each rail shall bear a weight of 12 tons midway between bearings of 3 ft. 6 in. without permanent set or more than ⅜ in. deflection, and 28 tons without breaking, or more than 4½ in. deflection, on same 3 ft. 6 in. bearings, or a blow from a weight of 1800 lbs. let fall from a height of 12 ft. with a deflection of not more than 2 in., and a second blow from the same weight dropped from the same height without breaking.



MECHANICAL TESTS.

The rail must stand without breaking a permanent deflection of 3 in. in a length of 3 ft. This deflection must be produced by one blow of a weight falling from a height of not less than 20 ft. upon the centre of a rail placed head uppermost upon two supports 3 ft. apart.

Pieces of rail to be tested to be 3 ft. 6 in. in length.

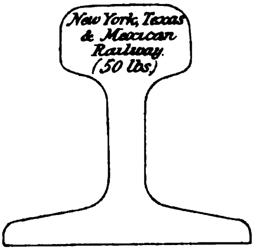


MECHANICAL TESTS.

Each rail shall bear a weight of 3 tons suspended midway between bearings 3 ft. apart without a greater set than ⅛ of an in., and without any permanent deflection whatever after the load has been on for one hour.

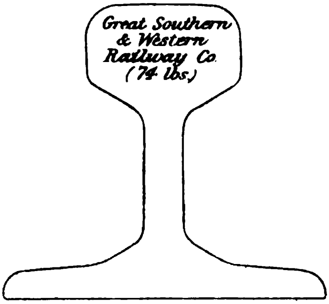
Also 2 strokes from a ball 1 ton weight let fall from a height of 10 ft. without breaking, or more deflection than 1 in. for each blow.

Scale ⅓



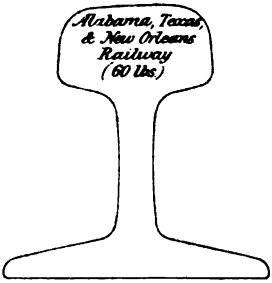
MECHANICAL TESTS.

Rails to be in stacks of 1000 each, and from each lot a number of rails not exceeding ½ per cent. will be submitted to the following tests:—Each rail shall be placed on bearings 3 ft. apart centre to centre, and shall support 5 minutes a weight of 10 tons without any permanent deflection, and in same position will support a weight of 20 tons without breaking, and on same bearings must resist a blow from a monkey weighing 1 ton from height of 12 ft. without showing any signs of fracture.



MECHANICAL TESTS.

The rails to be placed on bearings 3 ft. apart, when a ball weighing 1 ton is to fall three times upon rail between the points of support from a height of 9 ft.; deflection not to exceed 3 in.; and upon same bearings to bear 23 tons without permanent set, and 35 tons without breaking.

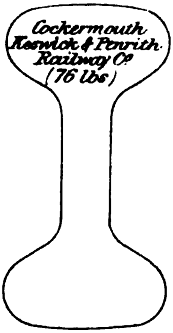


MECHANICAL TESTS.

1st. A whole rail being supported on wrought iron bearings 3 ft. 6 in. apart in the clear, and equidistant from both ends, a monkey weighing 1 ton will be allowed to fall freely upon the centre of the bearing from a height of 12 ft., and the rail must stand two such blows without showing the least sign of fracture. The permanent set caused by the first blow not to exceed 2 in.

2d. Another rail similarly placed must sustain a load of 10 tons for half an hour. No permanent set to appear after removal.

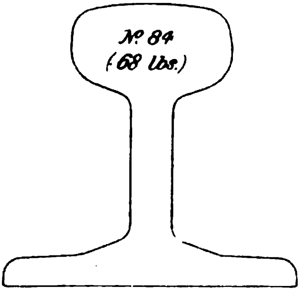
Scale 1/3



MECHANICAL TESTS.

1st. The rails to be placed on bearings 3 ft. apart and loaded on the centre with 20 tons for half an hour, shall have no permanent deflection.

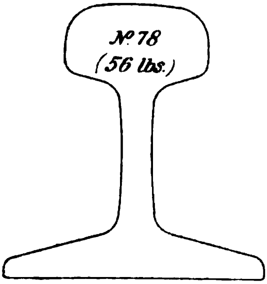
2d. The rails placed on same bearings 3 ft. apart shall not be broken by a weight of 1800 lbs. dropped from a height of 6 ft. on the centre between the bearings.



MECHANICAL TESTS.

A rail placed on bearings of iron 2 ft. 7½ in. apart, and should bear a weight suspended from the centre of 17½ tons for 5 minutes without leaving a permanent deflexure. The same rail should resist a pressure of 36 tons for 5 minutes without breaking or causing a fracture.

Pieces of rail placed on bearings same distance must resist a blow from a monkey weighing 14 cwt. from a fall of 20 ft. upon its centre.



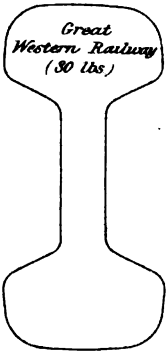
MECHANICAL TESTS.

1st. A rail on 3 ft. bearings must carry 13 tons 5 minutes without permanent set; on same bearings 26 tons without breaking.

2d. On 3 ft. bearings to stand a blow from a ball weighing 1 ton from a height of 15 ft. without showing any fracture.

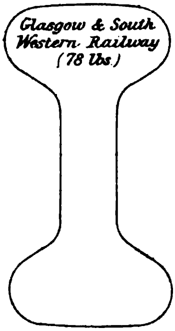
3d. Each half of the broken rail again placed on same bearings must stand a blow from a ball of 1 ton falling from a height of 15 ft. without showing any fracture.

Scale ⅓



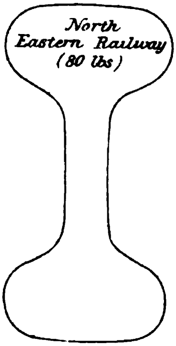
MECHANICAL TESTS.

Sample rails shall be tested upon and between solid cast iron bearings placed 3 ft. 6 in. apart, and letting fall upon their centre a weight of 1800 lbs. through a distance of 6 ft., noting the deflection at each blow.



MECHANICAL TESTS.

Each rail shall be capable to bear a dead weight of 20 tons midway between bearings of 3 ft. without permanent deflection, and 35 tons with not more than 1½ in. deflection; also two strokes from a ball of 1800 lbs. weight let fall from a height of 5 ft., and without showing any appearance of fracture or more than 1½ in. deflection.



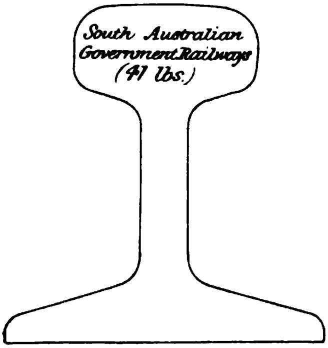
MECHANICAL TESTS.

Rails to be subject to test of two blows from a ball of 1800 lbs. falling 5 ft.

Bearings 5 ft. apart.

Rails must not contain less than 0·45 to 0·50 per cent. of carbon.

Scale ½

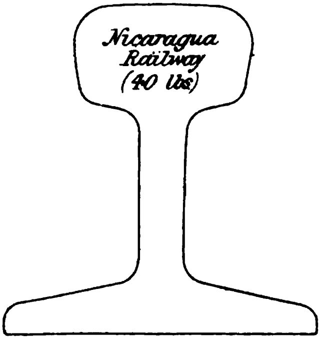


MECHANICAL TESTS.

A certain number of rails not exceeding 2 per cent. of the whole, will be selected and tested.

The rail being placed upon supports 3 ft. apart, a tupp weighing 7 cwt. shall be let fall upon it from the height of 10 to 16 ft., and the rail must stand 4 blows of this kind without breaking.

A dead weight of 10 tons shall be allowed to remain upon the rails in the same position for 10 minutes without producing permanent deflection.



MECHANICAL TESTS.

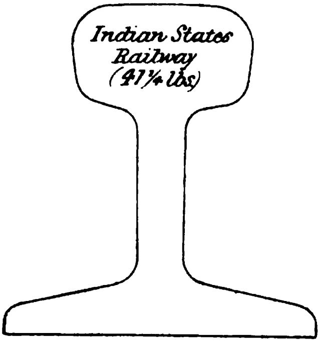
Four pieces of rail each 5 feet long will be taken from each day's make and placed on solid bearings 3 ft. apart, and shall stand the following tests :—

Two by dead weight of 12 tons suspended from the centre between the bearings; each sample shall carry this for 10 minutes without showing a greater deflection than ⅜ of an inch, or any permanent set exceeding $\frac{1}{16}$ of an inch.

Two by a weight of 1800 lbs. falling from a height of 6 ft. First blow, set not to exceed 2¼ in. ; 2d blow, set not to exceed 4¼ in. ; 3d blow, rail reversed, set to be reduced to 3 in.

Samples not to be cracked or broken.

Scale ½



MECHANICAL TESTS.

1st. A rail 7·25 metres long will be placed on wrought iron bearings 3 ft. apart in the clear and equidistant from its end, and a weight of 10 tons will be suspended from its centre, and its deflection under this weight must not exceed $\frac{3}{16}$ of an inch after the weight has been on the rails half an hour. No permanent set must appear upon the removal of the load.

2d. The rail will be supported as before, and a cast iron monkey weighing 1120 lbs. will be allowed to fall freely upon the centre of the rail from a height of 15 ft., and must bear two blows without the least sign of fracture. The permanent set caused by the first blow must not exceed 2 in.

3d. Experiments will be made upon whole rails with a falling weight of 10 cwt. The rails, when broken through, must show a perfectly sound and homogeneous fracture.

The rails must, on analysis, comply with the following conditions:—

The quantity of carbon must not be less than ·3 per cent. nor more than ·45 per cent.

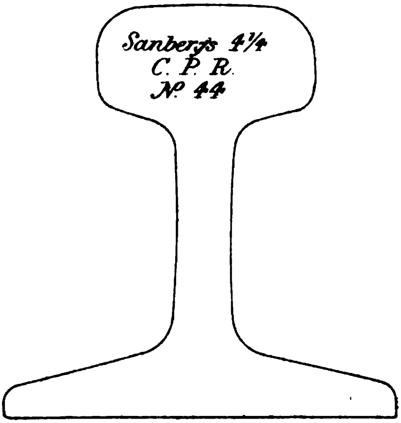
The quantity of silicium must not be less than ·06 per cent.

The quantity of phosphorus must not be less than ·06 per cent.

The quantity of sulphur must not be less than ·06 per cent.

There must be no other materials present except manganese and iron.

Scale ½



MECHANICAL TESTS.

The rails to be subjected to the following tests:—

One rail out of each 100 tons (or one or more rails taken at random out of each day's make, if so required) will be chosen and tested as follows:—

(*a.*) A portion of the rail placed on supports 4 ft. apart must stand without fracture a blow from a ball 1 ton in weight falling from a height of 18 ft.

(*b.*) Another portion of the rail similarly supported shall be submitted to successive blows from a ball weighing 3 cwt. from heights of 3 ft., 4 ft., and 5 ft., and the respective deflections are not to exceed ⅛ in., ¼ in., and ½ in.

If the first rail taken out of the 100 tons does not stand the above tests, the lot is to be divided by halves, and one rail of each half (50 tons) tested. If these tests are unsuccessful, the whole lot is to be rejected.

The falling weight test shall be continued until fracture results, and the facts duly recorded and reported.

APPENDIX.

MIDLAND RAILWAY, ENGINEER'S OFFICE,
DERBY, *9th May* 1882.

MY DEAR SIR,—Your favour of the 3rd inst. So far as time has allowed me, I have gone into the matter of the breakage of steel rails, as requested by you.

I find that during the last three years the breakages have amounted to ·009 per annum, but I am only able in 16 cases to give you the chemical tests, which I herewith enclose for your information.

As regards the wear of the surface of the rails, my book has been sent from Derby that would have given the information on that point, and I fear to await its return would make the information too late to be of service to you.

I consider the mechanical test to be the most serviceable and the simplest which can be applied, and I am not prepared to recommend any other.

I am much obliged for the copy of Mr. Sandberg's pamphlet.—Yours truly,

A. JOHNSTON,
Engineer.

J. S. JEANS, Esq.,
Secretary, The Iron and Steel Institute, Victoria Mansions,
Victoria Street, Westminster, S.W.

Steel Rails—Analyses of Drillings.

	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Copper.	Iron.
I. W. . . .	·304	·267	...	·241	·749	·028	98·781
II. W. . . .	·264	·071	·018	·225	·569	·021	99·361
III. W. . . .	·339	·410	·050	·231	·763	·021	98·630
No. 129 . . .	·252	·098	·002	·062	·042	...	99·544
,, 128 . . .	·354	·074	·001	·064	·008	...	99·499
,, 124 . . .	·287	·212	·003	·054	·030	...	99·414
,, 125 . . .	·491	·103	·004	·047	·022	...	99·333
N. . . .	·384	·024	·006	·021	·074	...	99·491
No. 50 . . .	·384	·106	·022	·213	·650	...	98·625
,, 60 . . .	1·100	·065	·074	·036	·592	...	98·133
,, 61 . . .	·371	·113	·063	·073	·803	...	98·577
,, 110 . . .	·40	·10	·09	·15	1·17	...	98·09
,, 111 . . .	·41	·09	·09	·14	1·06	...	98·21
,, 112 . . .	·41	·07	·10	·15	1·13	...	98·14
,, 118 . . .	·65	·042	·086	·103	·432	...	98·687
,, 130 . . .	·54	·079	·074	·071	·540	...	98·696

LANCASHIRE AND YORKSHIRE RAILWAY, ENGINEER'S DEPARTMENT,
MANCHESTER, 29*th April* 1882.

Return showing the Quantity of Steel Rails made use of each Year since their introduction in 1866.

Year.	Miles of steel rail (not miles of single *road*).		Number of rails that have failed.	
	Length laid down each year without deducting that pulled up.	Length existing at end of 1881.		
	Miles of rail.	Miles.		
1866	20	...	nil	The 69 broken rails bear a percentage of 4·2 per mile of rails used. MEM.—Standard length of rail used since 1877 is 24 feet. Prior to that we used 21 feet rails.
1867	18	...	,,	
1868	32	...	,,	
1869	40	...	,,	
1870	40	...	,,	
1871	50	...	1	
1872	52	...	2	
1873	80	...	1	
1874	90	...	1	
1875	190	...	2	
1876	204	...	7	
1877	170	...	14	
1878	146	...	9	
1879	150	...	18	
1880	200	...	7	
1881	160	...	7	
	1,642	1,460	69	

Less quantity displaced,	182
	1,460 miles of rail existing on the Lancashire and Yorkshire system (not including Preston and Uttoxeter and Lancashire Union lines) at the end of 1881.

STURGES MEEK.

Mr. Webb informs me that on the Lancashire and North-Western Railway the percentage of steel rails that failed in use after the test during 1880 was only ·088 per cent., and the greater part even of this is accounted for by a bad blow at one of the works. During the ten years ending with 1880 the percentage of steel rails that have failed in service on the Lancashire and North-Western Railway was ·135, and but for one or two exceptional cases would have been lower still.

With reference to the London and South-Western Railway, I am told that "the percentage of rails which have not passed the test and of those which have failed in service is so small that no special record has been kept of them."

On the North British Railway, again, the percentage of rails that have failed in service is so small that no record is kept of them, nor is the cause of failure recorded.

On the Highland Railway the tests prescribed have been almost entirely met, only one having broken in about every 1000 tons, while for two years past none have so far failed as to require their removal from the line.

It was decided that the discussion on Mr. Suelus' paper should be deferred until the Spring meeting.

The CHAIRMAN said there was only one more paper to be brought forward, viz., that by Mr. Massicks on a new hot-blast firebrick stove. There were on the programme three other papers by gentlemen who were not present; but had it been otherwise, the Council would have been under the necessity of holding them over until the next meeting in London, owing to want of time for their consideration.

The following paper was then taken as read, the discussion being deferred until the spring meeting of the Institute :—

ON A NEW HOT BLAST FIREBRICK STOVE.

By THOMAS MASSICKS, Millom.

Amid the conflict of opinion which prevails on the subject of hot blast stoves, I have some diffidence in presenting this paper for the consideration of the members of this large and practical Institute. I will at once say, that I do not now intend to deal with the entire question of hot blast stoves; still less is it my intention to make any remarks in disparagement of this or that particular form of stove.

This paper will deal, in as clear and concise terms as I am master of, with a hot blast stove now in successful working.

I venture to think that the question of heat for the blast furnace is, to the iron-smelter, one of the first importance; at any rate, my experience has been, until recently, that of anxiety and perplexity in reference to this matter.

The blast furnaces at Millom were built in 1865, and we there adopted the cast iron pipe stove; indeed there were then, I think, none other, excepting such as were in an experimental stage. In the course of a few years, we modified these stoves several times, each time, of course, with a view to improvement, but in every case we had to contend with burning of stove pipes, leakage of blast, and loss of temperature. Several ironmasters I now see before me will have a vivid recollection of the introduction of the firebrick hot blast stove, and I well remember going, about the year 1870, to inspect a stove of this class at the Ormesby Works, Middlesbrough, and, shortly afterwards, going to Stockton and Consett to see the late Mr. Thomas Whitwell's stoves in operation. The result was to lead us at Millom to adopt the Whitwell stoves for two new large furnaces we were then erecting. In succeeding years we removed six blast furnaces (our original plant), and put in their place four large furnaces, to which we also applied the Whitwell stove, but with some improvements on the first set of stoves of that description.

At the end of 1880, I and my friends purchased the blast furnace works of the Furness Iron and Steel Company, at Askam, in Furness. There were here four blast furnaces of quite the largest type in the hematite district, and with a very fine smelting plant in every respect, excepting the hot blast stoves. These were of the usual modern cast iron pattern; some of them, indeed, were in advance of this, and were Crossley's patent—a stove upon a stove, if I may so term it. We had, however, no hesitation in determining to sweep away all these stoves, and replace them with firebrick stoves. The question was, of what kind? We were fortunate in having at Millom an engineer of ability and large experience in this kind of work, and he and our furnace manager, Mr. Horace Massicks, designed, and we adopted, the stove which is the subject of this paper.

The drawings which are before you are, I trust, so clear that I need not take up your time with any lengthy description. It may be said that there is an apparent deficiency of heating surface in these stoves, as compared with some that are being constructed at the present time. I am quite aware of this, and in this stove provision is made to increase the heating surface at will. But I venture to assert that stoves made with small passages for the purpose of obtaining a large amount of heating surface cannot be kept clean without an immense amount of labour and time, and will not retain their heating surface very long. No better proof of this can be adduced than that the Whitwell stove in 1856 was able to compete most successfully against Cowper's stove, containing, probably, five times the heating surface, because Mr. Whitwell, by his improved means of cleaning the stove, was enabled to maintain the heating surface which he had originally, viz., about 9000 feet. I may point out that the reason we at Askam adopted the stove before you was that it secures a permanent heating surface and is easily cleaned, besides which it can be erected at a comparatively moderate cost. We also came to the conclusion that it was advantageous to have a number of small stoves rather than a few of larger and more costly construction.

I will just allude to a few of the advantages these stoves have over the iron pipe stoves:—

1. A very much greater temperature is obtained than can possibly be got from iron pipe stoves, with much less consumption of gas.

2. In all pipes, sooner or later, there is considerable leakage and back pressure, which throws a great amount of extra work upon the blowing engines. We had a notable instance of this at the Askam Works, which we have recently reconstructed. Two furnaces, when working with the iron pipe stoves above alluded to, were making about 500 tons per week each, with 22 to 24 cwts. of coke per ton of iron, the blast pressure at the engine being 5 lbs. per square inch, but only about 3¾ lbs. at the tuyeres. This was a very unsatisfactory state of things, and we had all the stoves taken down and replaced by seven Massicks & Crookes's stoves. The effect of this was, that instead of three blowing engines being necessary, two only were required, and the make of the furnaces went up to between 600 and 700 tons per week per furnace, with a reduction of from 4 to 5 cwts. of coke per ton of iron made, while there was no appreciable difference in the pressure of the blast in the hot blast main from that at the blowing engine.

The cost of the stove plant for two furnaces was about £5000, from which we had to deduct the value of old pipes and bricks, about £1000, making the cost of the stoves about £2000 per furnace.

I now beg to draw your attention to the special advantages which these stoves possess. The centre of the stove is the hottest part, and the outer courses of bricks are the coldest part, thus enabling this part of the brickwork to be of common brick. The bottom of the stove is also quite cool, being in immediate proximity to the chimney flues. These advantages will commend themselves to the observation of every practical engineer and furnace manager, as they not only are the means of protecting the iron work from injury by overheating the plates, but also, and from the same cause, there is less loss of heat by radiation. In practice we find this to be the case; and when a stove is laid off to be cleaned, a man can, in a few minutes, go underneath the cross flues, and all round the outer chambers, for the purpose of cleaning, without any personal inconvenience from the heat. Another advantage of the design is that there are no great massive walls necessary to protect the casings, 9 inches being the thickest wall except just that portion which forms the combustion chamber, and which is made of best quality half gannister bricks, 14 inches thick. It is the practice of all other makers of firebrick stoves to have at the hot chamber, against the wrought iron casing, from 18 to 24 inches of brickwork to protect the iron plates. This, in the case of the stove under consideration, is unnecessary, and there is a saving of space and of a great deal of material.

In designing this stove, the primary object has been so to construct it that every part, nook, and corner should be accessible for cleaning by means of a spring scraper, which can be applied without the removal of any of the brickwork in the arches. This is accomplished in a very simple manner. In the roof of the stove, over the centre of each segmental passage or group of passages, there is a small wrought iron pipe, H, sufficiently large to admit of a chain, so that, when it is necessary to clean the stove, the chain is lowered through this pipe to the bottom of the stove manhole, F, where it is attached to a spring scraper, K, made of the form of the passage required to be cleaned. The chain is then hoisted to the top of the passage, bringing with it the spring scraper which detaches all the dust from the walls, after which it is lowered, and the same operation goes on all round the store. The centre chamber has such a high temperature that all dust remaining there is melted into liquid slag, and is raked out from the bottom, after three or four months' working.

The valves, A B C, employed are of a most simple and effective type, and the liability to get out of order is reduced to a minimum. The admission of air for the combustion of the gas is obtained through valves, E, on each side of the branch, thence round a firebrick gas-burner, which is so constructed as to cause the gas to be thoroughly mixed with the air. After the burning gases have travelled to the top of the stove they enter a second combustion chamber, L, which is supplemented with air from a valve, M, in the apex of the stove, which valve is so adjusted as to give sufficient air to complete the combustion of the gas. This valve is self-acting, and closes as soon as the air is let into the stove.

Drawing No. 1 is a plan showing the arrangements I have just described.

Drawing No. 2 shows a stove of a much less costly design, yet one that will be found very successful where there is not a chimney flue available, or where there is not sufficient space for the larger-sized stove. Two such stoves are now being erected by the Millom Iron Company to supplement the Whitwell stoves working there. These stoves are estimated to cost about £600 each, and four of them will give a uniform temperature of 1300° to a furnace making 500 tons per week.

My experience is that uniform pressure and temperature of blast are most important for successful working, and this can be best obtained by a number, say, seven or eight stoves (such as those described) per pair of furnaces of average size. On the other hand, my belief is that those who elect to work with, say, two large stoves per furnace, will be liable to irregularity and stoppage, which will be a source of serious loss and disappointment.

I need hardly add that the operation of working these stoves is first to heat them with the waste gas from the furnace, after which the gas valve A and the chimney valve C are closed, and cold air valve D is opened to admit and allow air to pass over the heated walls through the hot blast valve B into the furnace. The course the air takes is indicated by the arrows, the burning gas taking exactly the opposite direction, but from the gas valve A to the chimney valve C.

THE DANUBE REGULATION WORKS.

In the course of Thursday's proceedings, Herr von Wese, on behalf of the Danube Regulation Commission, gave a description of the works carried out by the Municipality of Vienna for the improvement of that river. He said the necessity for the regulation of the Danube arose from the fact that the river formerly made four curves near Vienna, and the shore of the river had only a height of about eight or nine feet. In consequence of this, the whole country adjoining the river was exposed to inundations, principally in the beginning of spring, when the ice began to break up. The ice-floes blocking up the river, the water was thrown back, and the whole of the surrounding neighbourhood became inundated. Consequently, the landscape presented the appearance of a sterile waste, and nobody chose to select for his abode a place covered up nearly every year by the water of the Danube. Other consequences arising from the annual inundations were epidemics caused by the effluvia from the humid soil and a heightened mortality (forty per thousand). The communication between both shores also suffered from the same fact, no solid bridges crossing the river; and neither was it possible to erect landing-places for the ships, the level of the water varying between a menacing height at the time of the inundations, and great shallowness during the heat of the summer. From several rival projects there was ultimately selected a plan by which another regulated bed was dug for the stream, its length being 2100 metres, by 300 metres broad, and 3·5 metres in depth. An opening was made by which the stream entered this new bed, and the old one was in a great measure filled up. For yearly inundations, a waste district of country was reserved, which was separated by an embankment of earth, which secured the surrounding country from the rising of the river. The regulation of the Danube had proved itself to be a most useful work in all respects. The inundations ceasing, the mortality rapidly diminished (from forty to twenty-four per thousand), and the land adjoining the river being no longer exposed to floods, rose rapidly in value. By filling up the old bed of the river, land was recovered to the amount of 2,400,000 square metres. The navigation was also materially improved, as a low state of the water was no longer of such consequence as before. Along the river ten quays were erected, of a total length of about 1100 metres, on which large warehouses were built. A railroad following the shore of the new river served to unite all the railways of Vienna, and secured direct communication with every station. All these circumstances combined had increased the traffic, and it had now reached four times the dimensions of ten years ago. The continuation of this really grand work was to be a channel, uniting the Danube with the Oder, and another joining the Elbe, thus bringing together the northern seas and the Black Sea. This was a great project, of the highest importance, not for the traffic of Austria only, but for the traffic of Europe generally.

The CHAIRMAN said it might be expected that he would say a few words upon the important river works connected with the navigation of the Danube, which Herr v. Wese had been good enough to describe to them; but that was rendered entirely unnecessary by the fact that an English description of them had been prepared, and he would now only ask them, as time was limited, to return to Herr v. Wese a hearty vote of thanks for the trouble he had taken in describing what had been done in reference to the matter in question.

The CHAIRMAN then announced that the ordinary business of the meeting was now ended. They had, however, a little extraordinary business to consider. He was not going to make any speech on the subject, as that would be superfluous, and time was pressing. He would content himself with submitting to them a motion to the effect that "the thanks of the meeting be given to His Excellency the Statthalter of Lower Austria, and to the Burgermeister of the City of Vienna, for the courteous reception extended by them, on behalf of the Government and Municipal authorities respectively, to the Institute."

Mr. JEREMIAH HEAD, in seconding the resolution, said that, had they visited that city depending for support merely on the kind co-operation of the Viennese citizens, their meeting would no doubt have been to a considerable extent successful, and they would have received great courtesy and hospitality. But they must agree with him that the countenance given to them by the official representatives of the State and of the Municipality had added enormously to the interest, the enjoyment, and the *éclat* of their visit.

Mr. **Windsor Richards** moved, and M. **Pourcel** seconded, a resolution expressing the thanks of the members to "the Local Committee in Vienna, whose admirable arrangements had so much conduced to the success of the meeting."

Mr. **Snelus** next moved, and Mr. **Bauerman** seconded, a resolution conveying thanks "to the Local Committees in Buda-Pesth, Leoben, and Graz, for their excellent arrangements for the reception of the Institute in their respective towns."

Mr. **James Kitson** proposed, and Mr. **Gjers** seconded, a vote of thanks "to the various Austrian Railway Companies for the facilities afforded to the members of the Institute on the various excursions."

Mr. **Daniel Adamson** moved, and Professor **Wedding** seconded, a vote of thanks "to the various ironmasters and others from whom the invitation emanated, to the owners of works so liberally thrown open to the inspection of members, and to the Austrian iron and allied trades for the great hospitality accorded to the Institute."

Mr. **Whitwell** moved, and Mr. **T. Hugh Bell** seconded, a vote of thanks "to the City and Muncipality of Vienna for their hospitality, and for the interest shown in the meeting."

Mr. **Horton** moved, and M. **Noblet** (of Liége) seconded, a resolution thanking "the President and Society of Engineers and Architects for their friendly reception and for the free use of their rooms; and also the Scientific Club of Vienna for opening their rooms to the members of the Institute."

The meeting having passed all these resolutions by acclamation,

Professor **Peter** Ritter von **Tunner** proposed a vote of thanks to the Chairman. Their worthy President (Mr. Josiah

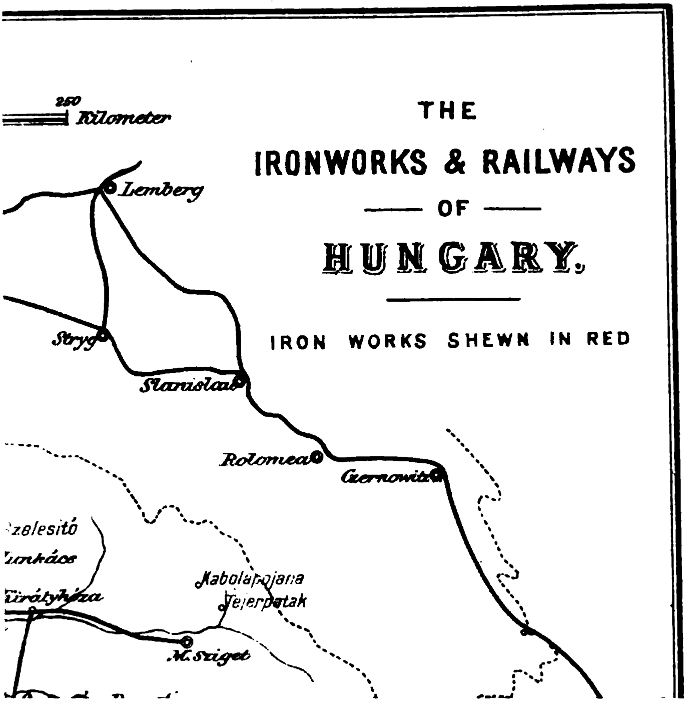
T. Smith) having been suddenly prevented by illness from attending, it was no easy task for his substitute, Mr. LOWTHIAN BELL, to take the Presidency of the meeting, as, besides being quite unprepared for the difficult work awaiting him, he had to preside over discussions in the English, French, and German languages. Only such an illustrious and capable man as their honoured Chairman would have been able to direct the discussions in a manner at once so brilliant and so satisfactory to all parties. He asked the Chairman to accept his individual thanks, and those of the whole assembly.

Mr. WINDSOR RICHARDS, in seconding the motion, said, in the regretted absence of their President through illness, they had reason to congratulate themselves on the splendid way in which their Chairman had conducted the proceedings.

The CHAIRMAN, in acknowledging the vote of thanks, which was heartily accorded, said he had no power of language in which he could express to his friend, Professor Tunner, his gratitude and thanks for the kind manner in which that gentleman referred to his humble exertions in connection with the discharge of duties which, of course, under all circumstances, were not entirely of an easy character. However, any difficulty that might have attended their discharge, he need not say to them, had been alleviated considerably by the very pleasant manner in which their discussions had been conducted. Members knew how to express their views with moderation and with consideration for those who differed from them ; but that, fortunately for the success of their Institute, had not prevented, and he hoped never would prevent, an expression of opinion on the matters brought before them, and independence of thought had been amply observed on the present occasion. At the same time he did not remember one single word that had fallen from any one who had addressed them that had been calculated to give offence to anybody. He concluded by thanking the members for the assistance he had received in the discharge of the duties of his very honourable position.

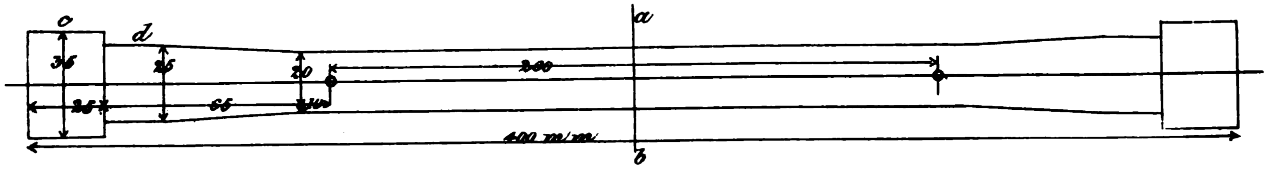
The proceedings then terminated.

PLATE 22.

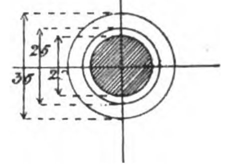

THE
IRONWORKS & RAILWAYS
OF
HUNGARY.
IRON WORKS SHEWN IN RED
250
Kilometer
Lemberg
Stryg
Stanislau
Rolomea
Czernowitz
zelesitó
Kabolapojana
Vejerpatak
M. Sziget

TO ILLUSTRATE DR. WEDDING'S PAPER
"ON THE ROYAL INSTITUTES FOR TESTING AT BERLIN."

NORMAL IRON ROD FOR TESTING. $\frac{2}{5}$ Actual Size.

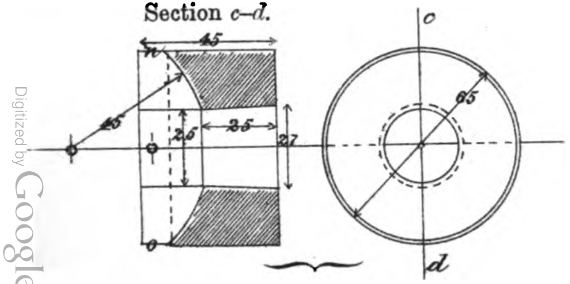


Section *a–b*.

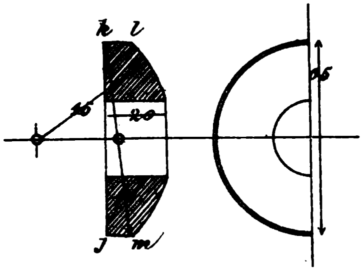


SPHERICAL SLIDE-COUPLINGS.

Section *c–d*.



Box A.



Moveable part B.

EXPLANATION.

The box A and the moveable part B consist each of two equal parts.

The two halves of B are laid round the neck D of the rod, the face KT holding the head C. Then the two halves of A are so laid round, that the spherical face LM slides on to the spherical face NO.

Journal of the Iron & Steel Institute

Ballantyne, Hanson & Co. Edinburgh & London.

TO ILLUSTRATE MR. GJERS' PAPER "ON THE SUCCESSFUL ROLLING OF STEEL INGOTS WITH THEIR OWN INITIAL HEAT."

FIG. I

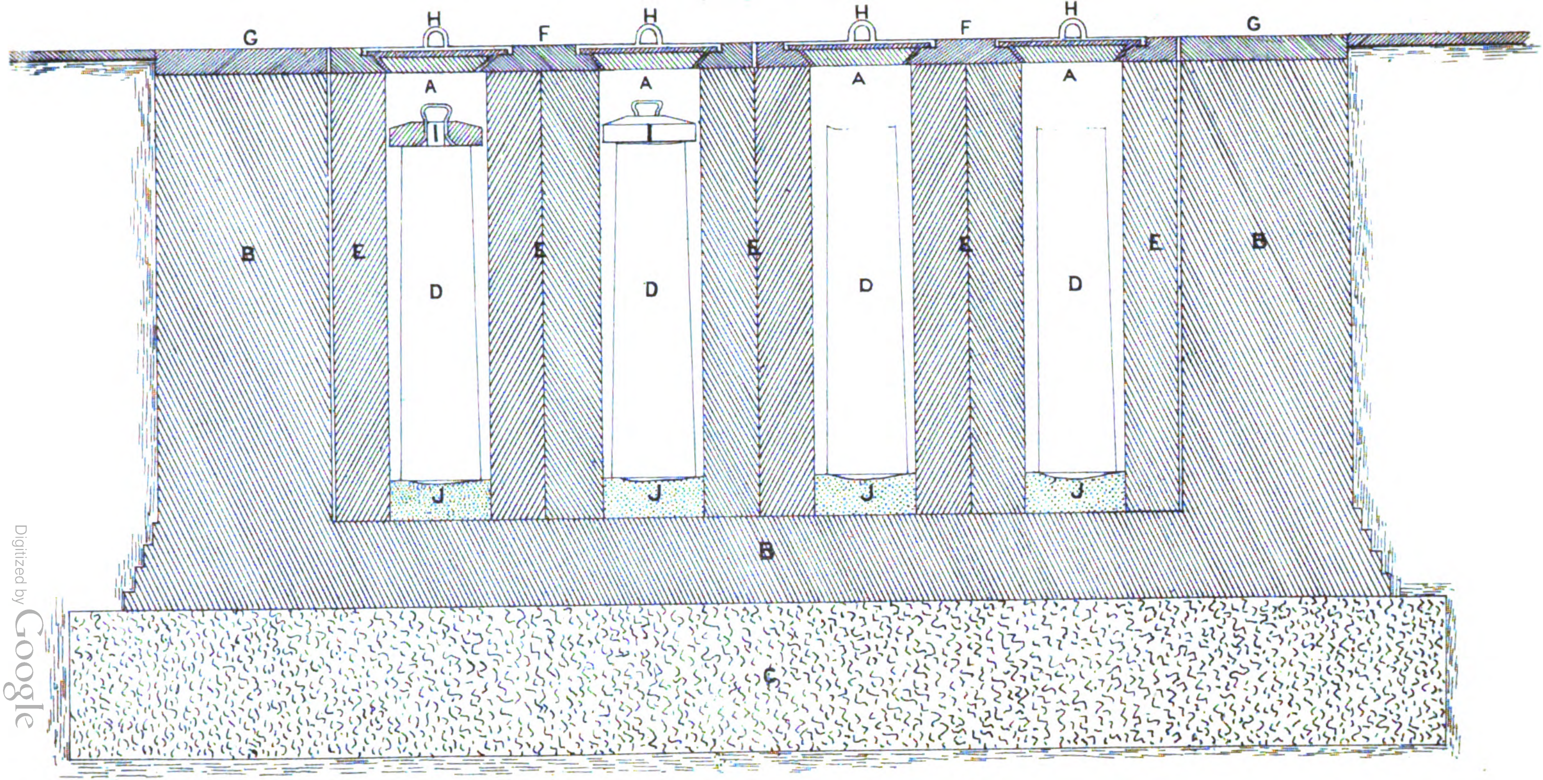


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PLATE 25.

TO ILLUSTRATE MR. GJERS' PAPER "ON THE SUCCESSFUL ROLLING OF STEEL INGOTS WITH THEIR OWN INITIAL HEAT."

FIG. 2.

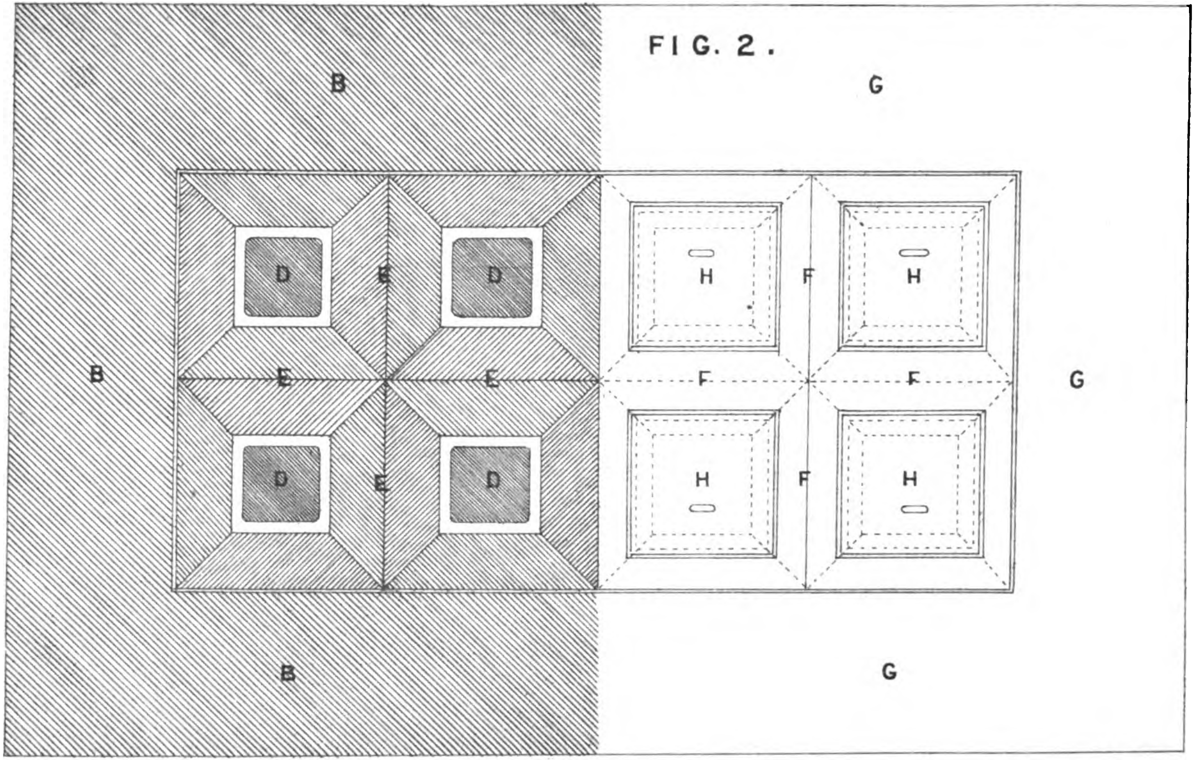

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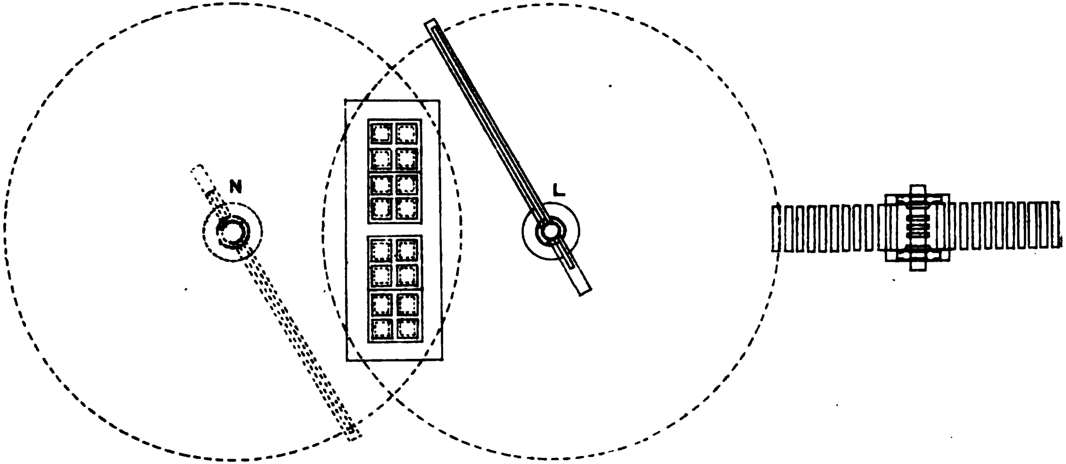
FIG. 3



GJERS' SOAKING PITS

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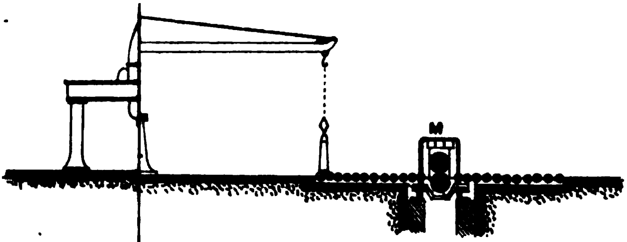
PLATE 27.

L ROLLING OF
T.”



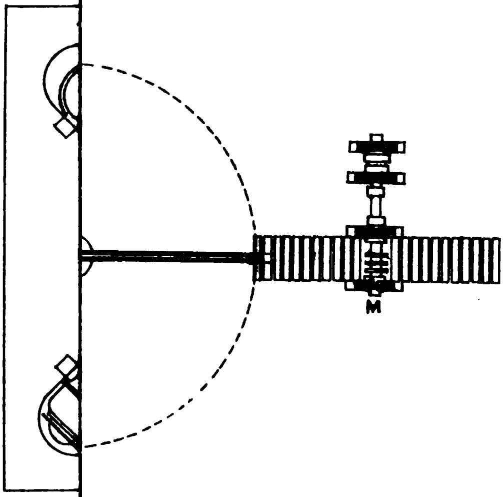


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PLATE 28.

STOVE.”

E Air Inlets for the Combustion of the Gas.

F Cleaning Doors.

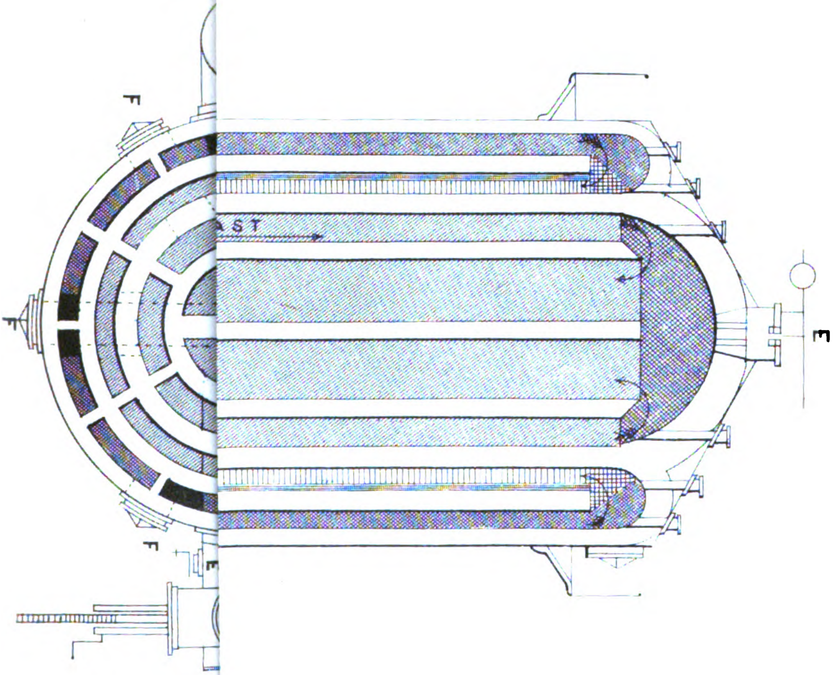

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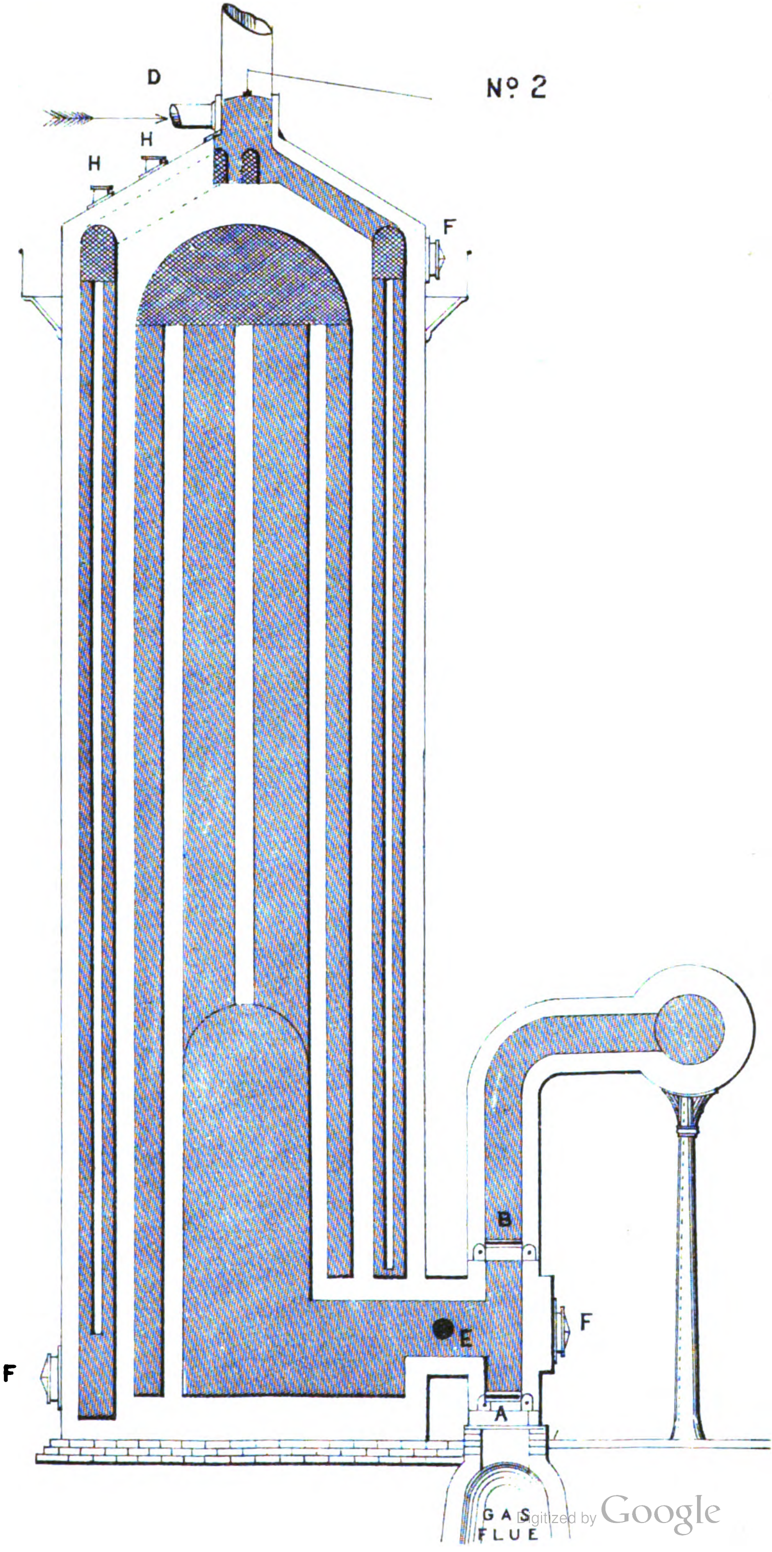
PLATE 29.

TO ILLUSTRATE MR. MASSICKS' PAPER

"ON A NEW PATENT HOT BLAST FIREBRICK STOVE."



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Journal of the Iron & Steel Institute

APPENDIX.

VISITS AND EXCURSIONS.

TUESDAY, SEPTEMBER 19TH.

THE IMPERIAL ARSENAL.

ON the afternoon of Tuesday, 19th September, the members were conveyed to the Imperial Arsenal, where they were received by Field-Marshal Baron Tilles, the Commandant, and by Colonel Streit, the Superintendent, and courteously conducted over the various departments. After making an inspection of the Waffen Museum and of the large collection of small-arms—in the former of which they saw on the ground-floor fifty-two white marble statues of Austrian heroes, while the latter afforded an opportunity of observing the gradual development of weapons of war from the cruder and earlier to the later and more perfect forms—the visitors went over the transport magazines and other stores, and ultimately arrived at the iron-foundries and fitting-shops, where a new machine was seen, which is used to bore both the trunnion bearings of a cannon at one operation. The chief specialty of the manufacturing department is the production of the well-known Uchatius bronze gun. This metal was stated to be an alloy of 92 per cent. copper and 8 per cent. zinc. The actual process of manufacturing the bronze guns was not shown, but it was explained by those in charge of the party. The metal is "drifted" by forcing through it by a hydraulic press, working at a pressure of 250 atmospheres, cast steel rings gradually increasing in diameter. Being convex on their outer surfaces, the rings do not cut the metal in any way, but rub against it in such a manner as to secure a great increase of diameter with a corresponding reduction of thickness. The small-arms used in the Austrian army are chiefly made by contractors outside.

Built between 1849 and 1855, the Imperial Arsenal forms a rectangular block of buildings, the four corners and centres of which are used as barracks, while the intermediate buildings are mainly used for the storage of the munitions of war. The number of men usually engaged in the Arsenal is about 3700.

The Werndl system has now almost entirely superseded the Wenzl, both for the rifles of the line and the carbines of the artillery. A Tighe-Hamilton dovetail-cutting machine is employed in making the packing cases for conveying ammunition, and is said to be valued for its accuracy and the quantity of work it turns out. In the same department a saw-frame was sawing out to the required arc portions of the felloes of gun-carriage wheels, while another machine, analogous to the wood-planing machine, was shaping the spokes. In one of the halls about 800 gun-metal Gatling guns were arranged ready for being sent off. By the side of the steel gun-metal cannon of 12 and 15 centimetres (about 4¾ and 6 in.) bore were a few guns of similar type and bore, cast from Styrian iron. The latter, however, are not now manufactured in Austria.

The preparation of the helical springs for receiving the recoil of large guns was watched with interest. This portion of the works is driven by one of two 16 horse-power horizontal engines on the Wood system, the other being kept in reserve.

The excursion for Wednesday, September 20th, was to the Kahlenberg, by way of the newly-regulated Danube, some particulars of which are recorded at p. 607, *ante*.

THURSDAY, SEPTEMBER 21ST.

THE FLORISDORFF LOCOMOTIVE WORKS.

As an alternative to the visits arranged for to the New Parliament Houses and the Imperial Palace at Schönbrunn, on the afternoon of Wednesday, the 20th September, an inspection of the locomotive works of Florisdorff found a place in the programme. The members who adopted this excursion were received and conducted over the various departments by Mr. Bernhard Demmer, the General Superintendent. In the erecting shops, a number of engines for the Paris, Lyons, and

Mediterranean Railway Company were found in course of construction. These engines had outside cylinders 21½ in. diameter, with 2 ft. 1½ in. stroke of piston, working on four complete wheels of 5 ft. diameter. The other wheels at the leading and trailing ends bring up the wheel base to the full dimension of nearly 19 ft. The axle-box brasses of these latter have a lateral movement in the boxes for easing the passage round curves; and the trailing axle has its axle-boxes outside of all, thus allowing the ash-pan to clear in going round curves. The fire-boxes are made very long, for the purpose of giving a large heating surface. All the holes in the boiler plates are drilled. Tweddel's hydraulic riveter is adopted for riveting the boiler shells. The boiler is cleated with brass plate. The valve of the saddle sand-box is worked by a rod and lever from the foot-plate. The boiler is fed with a single Giffard injector, and no pump. The buffer beams consist of wrought iron boxes with laminar springs inside. The cylinders weigh nearly a ton and a half, and are made of a mixture of iron containing—

Grey Styrian pig . . .	230
White Styrian pig . . .	175
Old castings	95
	500

At first 5 per cent. of spiegel was added by way of experiment, but it did not give a sufficient amount of resistance, which is specified to be 18 kilos. per square millimetre. The engines are provided with steam-reversing gear like the steam-steering gear of vessels. The reversing rod, on account of its extreme length, is guided by a slotted bracket and anti-friction roller. The tenders are arranged for carrying a new type of Westinghouse brake, exercising an equal pressure on both sides of the wheels. In the boiler-shop a 25-ton travelling crane was worked by an endless rope, whilst another, on the same principle, travels over and across it in the contrary direction. A 5-ton steam-hammer, made at the works and erected four years ago, is built up of ⅜-in. wrought iron plates and Bessemer steel girders. A complete set of Whitworth gauges is used for making duplicates of tools, &c., as they are required. The joints of all boiler fittings are made of spherical or dished forms, and these can only be prepared by corresponding gauges. The working of a special lathe for turning oval, conical, and eccentrical objects and making taps was interesting. In the first of these operations a lateral movement is given to both headstock and puppet, and in the second to the headstock only. A compound horizontal engine has been erected for driving some of the machines, and also for experiments intended to decide how far the compound system can be applied to locomotives. The boiler pressure is 180 lbs. per square inch, and the first shaft runs at 130 a minute. Altogether the Florisdorff afforded to members a good idea of perhaps the best type of locomotive practice in Austria.

FRIDAY, SEPTEMBER 22D.

EXCURSIONS TO STYRIA AND BUDA-PESTH.

Two alternative excursions were organised for Friday, September 22, the one to Leoben and Graz, in Styria, including the Erzberg and the ironworks of the Vordernberg valley, and the other to Buda-Pesth, the capital of Hungary. For both excursions trains were provided by the railway authorities on very favourable terms, that to Buda-Pesth being made up entirely of new carriages, now used for the first time, and affording the, to Englishmen, rather unusual experience of being able to move from one end of the train to the other. About 130 members and visitors proceeded to Pesth, while 100 others gave preference to Styria.

THE NEUBERG STEEL WORKS.

Leaving Vienna by the Southern Railway at seven o'clock in the morning, the party for Styria proceeded over the Semmering Pass, which a beautifully clear day afforded them an excellent opportunity of seeing to advantage. The first halt was made at the iron and steel works of Neuberg. One of the most important establishments of the kind in Austria, the works of Neuberg embrace blast furnaces and Bessemer and Siemens-Martin steelworks. A pamphlet, prepared by the directors and circulated among the members, states that the present Neuberg Works were founded in 1838. Ironworks, however, were carried on in the neighbourhood since 1331, although, up to the commencement of the present century, when they were acquired by the Government, the works were distributed over the Upper Mürz Valley. In 1869 the Austrian Government sold these works, along with others, to private companies, and in the spring of the present year they became the property of the Alpine Montangesellschaft. The two blast furnaces are each 43 ft. 7·6 in. high; their diameter is 5 ft. 11 in. at the base, 9 ft. 4 in. in the boshes, and 3 ft. 3 in. at the mouth. Their united aggregate annual production amounts to 12,000 tons of Bessemer pig, produced from charcoal and calcined spathic ore from the Company's own mines. The Bessemer department contains two converters of 4 tons 10 cwts. capacity, and produces 15,000 tons of ingots per annum. The following are analyses of the ores generally used, as charged into the blast furnaces after calcination :—

Composition.	Altenberg.	Solln.	Gollrad.	Eisenerz.
	Per cent.	Per cent.	Per cent.	Per cent.
Quartz and combined silica . .	17·20	12·05	14·30	7·05
Ferric oxide (Fe_2O_3)	70·60	72·70	70·64	67·78
Ferric protoxide (FeO) . . .	...	...	...	2·00
Manganic oxide (Mn_3O_4) . .	3·24	3·20	3·69	...
Manganic protoxide (MnO) . .	...	...	...	3·86
Cupric oxide	0·003	0·043	Trace	Trace.
Nickel and cobalt oxides . . .	...	...	0·095	...
Alumina	2·41	2·35	2·41	1·79
Lime	0·92	1·20	0·70	7·15
Magnesia	4·60	6·45	5·38	2·90
Sulphuric acid	0·170	0·377	0·003	0·110
Phosphoric acid	0·039	0·020	0·036	0·057
Carbonic acid and water . . .	1·10	1·70	2·60	7·60*
Metallic iron	49·42	50·80	49·45	49·00

The largest yearly production of each furnace is 6000 tons of Bessemer pig. The iron from the blast furnaces is run direct to the converters, but there are also two five-ton cupolas provided for remelting Mariazell or other pig when it is used. The composition of the pig (grey) is: iron, 91·96 per cent.; combined carbon, 0·89 per cent.; graphite, 2·8 per cent.; silicon, 1·6 per cent.; sulphur, 0·018 per cent.; phosphorus, 0·042 per cent.; manganese, 2·63 per cent.; nickel, 0·02 per cent.; copper, 0·037 per cent. The pig produced from the Eisenerz ore is said, however, to contain as much as from 4 to 5 per cent. manganese.

The Siemens-Martin department is composed of three furnaces, holding five tons each. They turn out unitedly 8000 tons of ingots yearly. In the ordinary practice of working, Bessemer steel is poured out in a liquid state into a well-heated open-hearth furnace. The furnace is then heated up to a high temperature, and the mass is allowed to remain in it for three or four hours, from 4 to 5 per cent. of waste steel being added in the interval. The latter is ultimately regulated by the addition of from 5 to 6 per cent. of spiegeleisen, which may have a small quantity of ferromanganese added to it.

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* Loss on ignition, CO_2 and water.

In regular working, 1000 lbs. of Bessemer pig are produced from 2150 lbs. of calcined ores, 140 lbs. of limestone, and 900 lbs. of charcoal; 1000 lbs. of liquid Bessemer iron and of steel ingots are obtained from 1087 lbs. of Bessemer pig, 307 lbs. of old iron and steel, and 8 lbs. of ferromanganese and spiegeleisen; 1000 lbs. of liquid Siemens-Martin iron and steel ingots require 307 lbs. of white and mottled pig, 710 lbs. of old iron and steel, 28 lbs. of ferromanganese and spiegeleisen, 15 lbs. of iron scale (*glühspan*), and 750 lbs. of pit coal; while 1000 lbs. of refined Bessemer steel are produced from 950 lbs. of liquid Bessemer steel, 43 lbs. of refuse from rolling-mills, 57 lbs. of ferromanganese and spiegeleisen, and 430 lbs. of pit coal.

The mills contain one 17-ton and one 6-ton steam-hammer, four other steam-hammers of various sizes, one plate-rolling mill with a 600 horse-power steam-engine, another with a 100 horse-power turbine, three cog-mills worked by hydraulic power, ranging from 50 to 100 horse-power, two large steam-shears, one hydraulic press of 400 tons pressure, and auxiliary machinery. There are three double puddling furnaces, three Siemens re-heating furnaces, 10 large re-heating furnaces for steel ingots, and 14 steam-boilers, 12 of which are heated by the waste heat of the puddling and re-heating furnaces. When in full work the rolling-mills and forges turn out per annum 7000 tons of heavy plates, 2000 tons of steel shafts and tires, 3000 tons of manufactured steel, 700 tons of machinery, and 2000 tons of liquid iron and steel, making a total of 14,700 tons of metal.

THE WORKS OF DONAWITZ.

After having examined the Neuberg Works, and partaking of luncheon at Mürzzuschlag, on the invitation of the Styrian iron trade, the party proceeded to examine the iron and steel works of Donawitz, belonging to the Oesterreische Alpine Montangesellschaft (Austrian Mining and Metallurgical Company). Founded in 1836 by Herr Franz Mayr, the Donawitz Works, which now employ over a thousand hands, and produce both puddled iron and open-hearth steel, commenced with the manufacture of puddled bar only. The prejudice then existing against iron made with any other fuel than charcoal was so strong that the new material had at first to contend against many difficulties, and the works only began to be successfully extended in 1845. Since that time they have been continually growing. The water-power, at first found sufficient for the whole works, is now concentrated in one mill, all the rest being driven by steam-power. The works came into the hands of the Innerberger Hauptgewerkschaft in 1872, and in the spring of this year were united to the Austrian Alpine Montangesellschaft, along with most of the other important companies of Styria and Carinthia.* Besides the main works at Donawitz, there are, under the same management, smaller works (Lancashire hearths) at Töllerl and Waasen, others at St. Peter and Göss, and a plate-mill at Gemeingrube. At the last-named works, a plate-mill, driven direct by a water-wheel, was erected as early as 1817.

The works contain two Siemens furnaces, one of five and another of seven tons. The gas is made from brown coal containing about 55 per cent. of carbon, and the weight of coal used is a little more than 50 per cent. of the weight of the ingots. The gas-producers work with air conveyed through pipes at a very slight pressure, about half an inch of water. The two furnaces together produced last year 4098 tons of ingot. The ingots are cast from the top.

There are eighteen puddling furnaces at Donawitz, each furnace having a *Vorwärmer*, or hearth for heating the pig, above and beyond the furnace proper, each set of flues serving to heat a boiler. All the puddling furnaces have step-grates to burn brown coal.† A charge consists, according to the quality, of from 5½ cwts. to 7 cwts. of pig, and 10 to 13 such charges are worked per shift of twelve hours, the fuel used in the same period being about 66 cwts. Each set of six puddling furnaces are worked with a 2½-ton shingling hammer, and separate shingling rolls, &c. The production of puddled bar in 1881 was 15,022 tons.

The rolling-mills consist of a large plate-mill (6209 tons in 1881) and six other mills, including a wire bar-mill. These six mills together produced 13,506 tons in 1881, of which 1003 tons were wire bar. The wire-mill on this occasion was rolling shingled blooms of 48½ lbs. to wire 0·2 in. diameter at one heat. The plate-mill is a three-high mill; all the others are two-high only, and none of them are reversing mills. Besides these mills, two others are used for steel, each driven by a water-wheel, their joint production last year being 1024 tons. It is the custom at the Donawitz Works to hammer the ingots for the finest quality of steel plates before rolling, second-quality ingots being taken direct to the rolls.

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* *Vide* Journal, No. I., 1881, p. 305.

† *Vide* Herr Kurzwernhart's paper, p. 451 *ante*.

After leaving Donawitz, the members proceeded to Leoben, where accommodation, partly at hotels and partly at private houses, had most considerately been provided for them by the local committee. In the evening the Styrian iron trade entertained the members at dinner in the Hotel Post, Professor Hofrath Ritter v. Tunner presiding. The toasts were, the "Queen of England and Empress of India," the "Emperor of Austria-Hungary," the "Iron and Steel Institute," "Success to the Styrian Iron Trade," the "Local Reception Committee," and "Professor Ritter v. Tunner." In the course of the evening a diploma of membership of the Leoben School of Mines was presented to Mr. I. Lowthian Bell, who, in acknowledging the compliment, claimed that it was conferred upon him, not because of his own merits, but because of his representing the Iron and Steel Institute.

THE IRONWORKS OF VORDERNBERG.

On the morning of Saturday, September 23d, the members who had stayed at Leoben overnight proceeded to inspect the blast furnace of Trofaiach, belonging to Prince Schwarzenberg. These works are situated about half-way between Vordernberg and Leoben, in a more open situation than any of the upper furnaces, so that all the materials charged have to be lifted through the full height of the furnace. The ore is calcined by the waste gas of the furnace in Filafer's patent kilns, of which there are ten, arranged in a rectangular block, 13·5 metres long by 4·25 metres broad. Each kiln has an internal capacity for 2·2 tons of ore, and is twice filled during the twenty-four hours, giving three tons of roasted from 4·5 tons of raw ore charged. The working of the kilns is regulated by the addition of more or less small ore, but when large ore alone is used the production is increased by one-half. The furnace stack is surrounded by an outer casing at a considerable distance from it to prevent loss of heat by radiation. The intermediate annular space is closed both above and below, and encloses a large volume of air, which, being stagnant, remains at a nearly uniform temperature of about 60 deg. Cent., the utmost variation between summer and winter being only 5 deg. The outer casing forms an imposing-looking tower of masonry, the lower part being square, 11 metres in the side and 5·6 metres high, with a slight taper upwards, each of the four sides being pierced by a large round-headed tuyere arch. The upper part is octagonal, also tapering, in a height of 11 metres, from 10 metres in diameter below to 8½ metres at the level of the charging platform.

The furnace stack, which is scarcely more than one-third of the diameter of its outer casing tower, is made up of two walls. The outer one, of common bricks hooped with iron rings, is carried upon six cast iron columns of the same height as the main tuyere arches, and carries the tunnel-head chimney above the charging platform. The inner stack stands entirely free within the outer one. It is built of fire-brick. The interior is nearly cylindrical, being formed of two acute conical portions joined by a cylindrical portion at the boshes. The leading dimensions are :—Height, total, 15·900 metres; height of lower cone, 4·109 metres ; height of cylindrical boshes, 2·184 metres; height of upper conical stack, 5·373 metres ; diameter of hearth, 1·580 metres ; diameter of boshes, 2·580 metres ; diameter of throat, 1·100 metres ; cubic volume of stack, 58 cubic metres.

Experience has shown that there is no considerable wear in the stack of these furnaces, except in the lower part near the hearth, which requires renewal after five or six years of continual working. Iron supporting columns are therefore used, as in the outer casing; but they are not so tall, leaving only a height of two metres of hearth proper, that can be rebuilt when necessary. The tuyere plane is 530 mm. above the hearth bottom. There are six bronze tuyeres, the two lower ones blowing into the centre, while the axes of the two middle ones are laid 80 mm., and those of the two front ones 150 mm. off the centre line. The blast nozzles vary, according to circumstances, from 46 mm. to 70 mm. in aperture. The gas trap is formed by a sheet iron cylinder, 1·10 metres diameter and 2·2 metres deep, suspended in the throat, which is correspondingly enlarged to form a ring flue. The opening of the gas flue, which is 948 mm. diameter, is 1·3 metres below the furnace top, and is fitted with a balanced valve for shutting off the gas when it becomes necessary to clean the flue, at which time the gas is allowed to pass into the air by an opposite passage connected with a chimney. At a depth equal to half the height of the furnace the gas main passes into a cylinder of 1·58 metres diameter, terminating below by a funnel and pipe closed by a water joint, where the dust carried over is deposited, and the purified gas is delivered by a lateral tube to the conduit leading it to the kilns and stoves. The latter are a modified form of Gjers' well-known pattern, and contain twelve pipes of elliptical section, 461 mm. by 106 mm., giving a total length of travel for the blast of 55 metres. The heat attainable is 555 deg. Cent.; but it is not found desirable to go above 340 deg., owing to the ready fusibility of the ore, which is liable to cause obstruction at the tuyeres if the blast is too highly heated. The blowing engine, driven by an overshot wheel of about 80 horse-power, has two horizontal cylinders, of 1·264 m. diameter and 1·180 m. stroke, the suction valves, which work against counter-springs placed in the cylinder cones, giving a minimum clearance space. The materials smelted are calcined spathic ore, of about 46 per cent. metal, fluxed when necessary with silicious clay and puddling and heating furnace cinder. When the latter are used beyond a fluxing quantity, caustic lime is added, which is burnt in the ordinary gas roasting kilns used for the ore, and charged hot. The fuel used is exclusively charcoal, about three-quarters of it being from soft coniferous wood, and one quarter from hard wood, principally beech. The former is derived from the forests of Upper Styria, while the latter is drawn from a much wider area, including Southern Styria, Carinthia, Hungary, and Croatia. On a large average the soft coal weighs 140 kilos. and the hard 230 kilos. per cubic metre. The fuel is charged by two waggons at a time, of 0·75 cubic metre capacity, or 1·5 metres per charge, and the burden of ore and fluxes mixed in two waggons, together of 750 kilos. The ore waggons have conical drop bottoms, which distribute the contents towards the circumference of the furnace, while the charcoal is, if necessary, levelled by hand. The number of charges passed through the furnace is, under ordinary circumstances, ninety in twenty-four hours; but with hard driving the number may be increased to 125—the former corresponding to a production of 30 tons and the latter of 40 tons per day. Under the most favourable circumstances the fuel consumption is about 65 per cent., or 13 cwt. per ton of metal produced. The furnace is tapped at intervals of two hours, the metal forming a plate about 2 m. square and 577 mm. thick, weighing up to 58 cwt. A piece of solid metal is placed upright in the bed before tapping, forming a handle to which the crab chain is attached for drawing the plate out when solidified. When cold, it is broken up by hand or under a falling weight into pieces about a foot square, for the refining and puddling furnaces, when the make is, as is usually the case, white refining iron. Occasionally, however, a close, dark grey metal, suited for specially strong machinery and chilled castings, is made. The Trofaiach blast furnaces were entirely rebuilt in 1871, and are at the present time regarded as the best blast furnace plant in Styria.*

The programme of this day's work also included visits to two other blast furnaces in the Vordernberg Valley, known as "Radwerk No. 13" and "Radwerk No. 14." The principal dimensions of the former are:—Diameter at base, 3 ft. 8 in.; † at the boshes, 6 ft.; at the top, 2 ft. 6 in. The boshes are 7 ft. above the base, and the whole furnace is 28 ft. high. The yield is 10 tons in twenty-four hours. The blast-engine has two oscillating cylinders of 3 ft. 9 in. diameter and 3 ft. stroke, with a capacity of 33 cubic ft.; being worked at the rate of eight strokes per minute, it yields 3060 cubic feet of cold blast. The pressure is equal to 2½ in. of mercury. There are two tuyeres, having each 1¾ in. diameter. One charge of coal amounts to 172 bushels, and one of ore to about 4½ cwts., without the flux. A "campaign" lasts four years, and the annual production is 3600 tons. The official returns show that the net yield of the ores amounts to 46½ per cent. To produce 100 lbs. of pig 83½ lbs. of charcoal are required.

The dimensions of "Radwerk No. 14" are:—Diameter at base, 4 ft. 6 in.; ditto at the boshes, 7 ft.; ditto at top, 4 ft.; height from base to boshes, 7 ft.; height of cylindrical boshes, 6 ft.; ditto from top edge of boshes to top of furnace, 29 ft.; total height of furnace, 42 ft.; capacity of furnace, 1070 Austrian cubic ft. = 4447 cubic yards. The tuyeres are 1 ft. 4 in. above the base stone, and they enter the furnace to the extent of 3 in. There are twelve of Filafer's patent roasting furnaces, two and two abreast. Their dimensions are:—Length, 4 ft. 6 in.; height, 8 ft. 6 in.; width, 1 ft. 8 in.; capacity, 63 cubic ft. The aggregate yield of these twelve furnaces is 40 tons in twenty-four hours. For producing hot air the so-called Westphalian apparatus are used, each of which consists of 24 horizontal tubes in six superincumbent rows, and connected together by horse-shoe pipes. The section of the tubes is oblong, being 13 in. in height and 3½ in. wide. The heating surface amounts to 350 sq. ft. There is never more than one apparatus at work, which raises the temperature to between 390° and 482° Fah.

The blast is supplied from one vertical cylinder, 5 ft. 9 in. in diameter and 5 ft. stroke; capacity, 125 cubic ft. It works at the rate of 7½ revolutions per minute. The hot air is conveyed to the furnace by three tuyeres of 1 ft. 7½ in. in diameter. The regulation takes place by means of a dry governor of thick iron plate, 7 ft. in diameter and 66 ft. long, holding 2500 cubic ft., and being an integral part of the blast. The lift is worked by hydraulic power, the charcoal being raised 30 ft. and the ores 48 ft. high. That power consists of a fall of 26 ft. 3 in., and a minimum quantity of 10 cubic ft. per second, representing 34·5 horse-power in winter, which is advanced to 50 horse-power in summer. The motive power is supplied by an overshot water-wheel, 22 ft. 8 in. in diameter and 10 ft. 6 in. wide, weighing 23 tons, working at a circumferential speed of 5 ft. 7 in. per second, and making 47 revolutions in a minute, its speed being to that of the blast as 5·8. This motor is assisted by a small 20 horse-power turbine, constructed according to Legeure's plan. The production of 1000 lbs. of pig requires 701 lbs. of charcoal, 1282 lbs. of calcium, and 427 lbs. of uncalcined ores, 356 lbs. of scoria, 33 lbs. of clay flux, and 35 lbs. of lime flux; total, 2133 lbs. of raw material The annual production amounts to 8087 tons of pig iron.

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* Further details of the conditions under which spathic iron ores are smelted in the Vordernberg Valley will be found in the *Journal*, No. I., 1882, p. 286, and in the paper of Mr. I. Lowthian Bell on "Comparative Blast Furnace Practice," p. 534, *ante*.

† The measurements for "Radwerke Nos. 13 and 14" are given in Austrian feet. 1 Austrian foot = 1·037 English foot.

THE STYRIAN ERZBERG.

At 9.40 A.M. the company reassembled in the little village of Vordernberg, where carriages waited to convey them up the mountain-side to Präbichl. The presence of so many strangers excited the interest of the mountaineers. Decorations met the eye on every side. Men, women, and children turned out to watch the procession as it drove up the hill, and some of the white cattle and goats which browse on this portion of the great Alpine range were covered with wreaths of flowers to give greater *éclat* to the occasion.

The Erzberg (iron mountain) is described by Mr. Bauerman * as a conical mountain-mass on the watershed of the Enns and the Mur, the highroad from Gratz to Steyer, which passes up the Vordernberg valley from Leoben, crossing it on the Präbichl pass, and descending the Eisenerz valley, reaches the Enns at Hieflau. The highest point above the sea-level is about 4800 ft., and about 3000 ft. above the town of Eisenerz. The deposit nearly follows the surface contour of the ground, so that it was formerly stated that the entire mountain was solid ore, but it is now known to be really a bedded mass included between limestones, which lie upon old schists, probably Devonian, and covered by the slaty beds of the Werfen series, which are of Triassic ages, and are enormously developed in the Tyrolese Alps. The ore is a finely grained spathic carbonate, which when unweathered contains from 40 to 42 per cent. of iron, 1 to 2 per cent. of manganese, and 2 to 3 per cent. of magnesia, with only very little lime, usually under 1 per cent. When altered by exposure to the air or infiltration of water, it changes to the so-called brown or blue ore, a rusty red limonite, averaging 54·4 per cent. of iron. This was the mineral sought by the primitive miners as being alone best suited for direct reduction in open fires, and the fissures were followed by small and tortuous levels, driven by pick and gad; the unweathered white ore, locally known as Pflinz or spangles, from the glitterings facets of the spar, was abandoned as waste. In places the admixture of magnesia and lime becomes so great as to render the ore worthless, producing the triple carbonate known as ankerite, the proportion of iron being reduced to 25 per cent. and below. At the base of the deposit the ore is somewhat silicious from the presence of small strings of quartz; but this condition is exceptional, the bulk of the produce being prominently of a basic character, and almost absolutely free from sulphur and phosphorus. The average furnace yield is 37 to 38 per cent. on the raw, and 51 to 52 on the calcined ore, the charges being usually so combined as to yield 48 per cent. on the average. The greatest real thickness of the deposit is about 500 ft.; but from the change in the inclination, which is at a low angle at the base and becomes very steep at the summit, the apparent thickness is much greater, the ore in a more or less pure condition appearing under foot for nearly 2000 ft. in height on the mountain side. From the configuration of the ground, the deposit was attacked at different levels by the works on opposite sides, and by an arrangement made as far back as 1524 the upper part was appropriated to the furnace proprietors or wheelmasters, *Radmeister*, on the Vordernberg side, and the lower to those in the Eisenerz Valley. As far back as 1625, the rights of the latter proprietors, consisting of nineteen furnaces with their associate forges, roads, and forests, were consolidated into one adventure known as the Inneberger Hauptgewerkschaft, while the furnaces or wheel works of Vordernberg remained independent until 1828, when the mining rights of thirteen proprietors were united, but the last one did not come into the combination until 1871. Since the commencement of the present year the works in both valleys, together with the principal ore mines and furnaces of Carinthia, have become the property of the Alpine Montangesellschaft.

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* *The Engineer*, 6th October 1882.

On the Eisenerz side the workings were entirely carried on in the open, in regular terraces which cover a surface of about seventy-eight acres. Twenty-six terraces, with a total height of about 1500 ft., are now worked, and there is room for five more up to the Vordernberg boundary. From 500 to 600 men are employed in winter and about 1250 in summer. The transport of the ore is effected by a combination of vertical shafts or mills and horizontal railways and inclined planes, numerous large reservoirs being interposed at intervals for containing the winter supply. Near the bottom of the hill is a series of fifty-eight calcining kilns heated by wood or small coal. The calcined ore is loaded in railway trucks and drawn by horses to the Eisenerz railway station, whence it is distributed partly to the Company's distant furnaces at Hieflau, Zeltweg, and Schwechat, a portion being smelted on the spot, and the remainder sold to other works. The annual production of the Eisenerz side is from 250,000 to 300,000 tons.

On the Vordernberg side of the mountain the workings lie between 3500 ft. above the sea-level and the summit, nearly 1500 ft. higher, so that open working can only be carried on during the six summer months. Partly on this account and partly because of the thick surface covering, the method of underground working has been very largely developed. The open workings occupy about forty-five acres and the mines about twenty acres more. The system of working is by broad pillars or panels, the ore being taken away, either parallel or perpendicular to the main levels, according to the direction of the jointing of the rock. The excavated spaces are packed with waste, derived mainly from the surface workings. The ore raised during the winter is stored till the following summer, when it is picked and broken.

The transport of the ore to Vordernberg is also confined to the summer, when about 200,000 tons have to be carried, cleaned, and stored for winter use. The arrangements for this purpose are in the main the same as those originally adopted in 1830. The principal means of transportation is a railway about 3½ miles long, starting from about the middle level of the workings, and passing through the Präbichl ridge by a tunnel to the Handlalp, in the Vordernberg Valley. The ore from the upper workings is passed down by shafts, while that from below is raised to the loading-place by three inclined planes, one worked by steam power, and the other two by water balances. The railway has a gradient with the load of 1 in 100, and was originally worked by horses, but in 1878 traction by locomotives was adopted. The gauge of the line is 3 ft. The curves and tangents are in the ratio of 30 to 70, the average radius of the former being about 185 ft., and the minimum, which, however, occurs only in two places, about 153 ft. The super-elevation of the outer rail varies from 1 in. to 2 in., according to the radius. The locomotives are tank engines of Haswell's construction, such as were originally used for underground traction in the collieries in the Banat. They weigh 11 tons in working order, and take a train of thirty-five waggons with a net load of 98 tons downhill at a speed of nine miles an hour. The return journey with the empty train and engine, together about 46 tons, is run at fifteen miles an hour. The fuel consumption on the double journey is about 150 lbs. of Leoben coal. Usually ten trips are made in twelve hours, and from May to August the line is worked day and night. At the end of the locomotive line the ores are discharged into a covered reservoir, where they are loaded into other waggons which perform the remainder of the journey to Vordernberg by a combination of inclined planes, passes, and railways—on a falling gradient of 1 in 110—which are worked partly by men and partly by horses, the further difference of level being about 1170 ft. from the end of the railway to the upper end of the town of Vordernberg. The most interesting features in this part of the system are the inclined planes, which are about a quarter of a mile long, at an inclination of 14 deg. from the horizontal, the loaded trucks being carried crosswise on a platform waggon. The load, of 9¾ tons gross, or 5½ tons net, is lowered at the uniform rate of about 430 ft. per minute by an iron wire rope winding on a conical drum of 115 in. maximum, and 101 in. minimum radius, making seven and a half revolutions per minute. The work due to the acceleration of the descending load in the lower part of the journey, which is equivalent to 60 or 70 horse-power, is absorbed by a continuous brake, consisting of a four-armed paddle revolving in a cistern under a head of about 5 ft. of water at about six times the speed of the main drum. This arrangement, which is a reproduction on a large scale of Joule's apparatus for determining the mechanical equivalent of heat, was viewed with great interest by most of the members present. It has been at work since the year 1846, and the motion of the load is so perfectly regulated that the iron wire ropes have a working life of fifteen years, the average day's work being 300 waggons of 5½ tons lowered. At various points on the lower railways large covered reservoirs are provided for storing the ore, the winter being too severe to allow of its being left in the open. There are five of these reservoirs, the largest resembling barns or granaries, and having a total capacity of about 140,000 tons. There are also sixteen calcining kilns with a productive power of about 70,000 tons yearly. The product, which for the present year is estimated at 212,000 tons, is entirely consumed in the blast furnaces of the Vordernberg Valley, already described.

From the Erzberg the party was conveyed again to Vordernberg, and thence by special train to Graz, where a local committee, under the presidency of Director Prochaska, had made admirable arrangements for their reception. On Monday morning the members were entertained at breakfast in Daniel's restaurant by the City authorities, and cordially received by Burgermeister Kilnzl and Baron Washington, whose welcome was suitably acknowledged on behalf of the members by Mr. I. Lowthian Bell. The members then proceeded to visit

The Graz Steelworks.

From an account of these works, furnished by Herr Prochaska, the director, it appears that they were originally founded for the purpose of working up the old rails of the Southern Railway Company into new rails, tyres, axles, &c. In 1864 a Bessemer department was added for the production of steel and steel-headed rails; but on the introduction of the Siemens-Martin process in the year 1877, the Bessemer works were given up. As now constituted, the works contain four Siemens furnaces, two of them taking 5½, and the other two 10 to 12½ ton charges. The regenerators, instead of being immediately below, are in front of the furnaces, and the gas is introduced at the full temperature of its production without being previously cooled by passing through a rising pipe and horizontal main, which does away with the difficulties produced by the deposition of tar and other condensible products. The gas and air admission passages in the furnaces are laid with their axes converging towards the centre of the hearth, both in the horizontal and vertical planes, so that the point of maximum intensity of the flame is in the middle of the bath, which not only gives a better utilisation of the heat, but protects the roof. The roof will stand from 300 to 600 heats without renewal, the furnaces being kept at work for six or eight months continuously. The charge for rail steel consists of about 80 per cent. of old malleable rails, which are dissolved in a bath composed of one-third grey coke pig from

Schwechat and two-thirds white charcoal metal from Vordernberg, with a final addition of about 3 to 4 per cent. of spiegel and ferromanganese. The steel contains:—Silicon, 0·3 to 0·4 per cent.; carbon, 0·4 to 0·6 per cent.; manganese, 0·45 to 0·65 per cent.

The consumption of melting coal is about 60 per cent. of the weight of the ingots in the large furnaces. The latter have a large annular casting pit about 40 ft. in diameter, with a central ladle crane. The ladle is so deep that the stream of metal would issue with too great a velocity if allowed to flow into the moulds direct, and the current is therefore moderated by interposing a shallow trough with two spouts, which is slung below the top hole of the ladle and allows two moulds to be filled simultaneously, with a corresponding reduction in the velocity of the stream. When the demand for rail ingots is insufficient to use up the whole of the steel in the ladle, a proportion of ferro-silicon, previously melted in a crucible, is added, and the remainder is cast into crossheads and other parts of locomotives, crossings, &c., the addition of the silicon producing perfectly sound castings. The rail ingots of two-rail lengths are reheated in a Bicheroux furnace, heated with Köflach lignite, having a bed about 25 ft. long with eight working doors, and an inclination towards the fire-bridge of 10 degrees.

As the gas is wholly produced with brown coal, the duration of a charge is longer than it otherwise would be, and usually extends to nine or ten hours. From the large furnaces, a production of 16,000 tons, and from the smaller, 8000 tons per annum is obtained, the total annual production of the works being about 24,000 tons. The usual charge per ton of ingots produced is 303 kilos. of pig iron, 725 kilos. of old iron, and 16 kilos. of ferromanganese, while the consumption of fuel is 750 kilos. per ton of ingots made. The liquid charge is decarbonised down to ·12 to ·14 per cent. of carbon, and then recarbonised with ferromanganese. The steel coming from the furnace is not poured direct into the moulds, but passes first through a small vessel, and thence into two moulds simultaneously; by this means an undue pressure on the ladle is avoided.

The rolling-mill proper consists of two sets of rolls. In the first, the preparatory work is done by three rolls, the ingots being raised and lowered by hydraulic pressure. The stoves for the preliminary heating of the steel hold 20 ingots, and are worked continuously, the cold ingots being brought in from above and the heated ones taken out from below, each ingot having to pass through the whole length of 26 ft., and being turned round and round until it is thoroughly heated.

From 70 to 80 tons of steel are heated in this stove in twenty-four hours. The flame proceeding from this stove also heats a cylindrical steam-boiler of 49 feet in height. From the first mill the rails are taken to the second, in which they are finished. Only one-half of the output of these mills is used by the Südbahn Company; the remainder is supplied to the trade. Besides rails, all kinds of materials for fixing rails, such as fishplates, spikes, screws, &c., are manufactured at the Graz Works.

After an examination of the steelworks, the members were shown over some adjoining wireworks and a large boot manufactory. Luncheon was subsequently partaken of in Daniel's restaurant, on the joint invitation of the city authorities and the Southern Railway Company. During luncheon, the attendant band performed a march specially composed in honour of the Institute.

EXCURSION TO BUDA-PESTH.

The members of the Institute who selected the Buda-Pesth excursion left the Staatsbahnhof, Vienna, by a special train provided by the Austrian State Railway authorities, at nominal fares, early on the morning of Friday, September 22. At Pressburg, where the train stopped a short time, an elegant luncheon was provided by the Staatsbahn in the station buildings. Pesth, which is 170 miles from Vienna, was reached about three o'clock, and, on alighting, the party was received by Ministerialrath Anton von Kerpely, Director of the Staatseisenwerke, and by Herr Rath, the Oberbürgermeister of Pesth, at the head of a large local committee. Herr Rath welcomed the "eminent representatives of the great iron industry, the active supporters of that craft which turns iron to useful purposes, and thus increases the material prosperity of the community." He expressed the hope that the short stay in the Hungarian capital might make a pleasant impression. Mr. James Kitson, of Leeds, one of the Vice-Presidents of the Institute, duly returned thanks, and called for three cheers for the Hungarian committee, which was responded to by the Hungarians with shouts of "Eljen!" that is to say, "*Vivat!*" The members were then drafted off to their hotels.

In the evening, a grand and thoroughly Hungarian banquet was given to the visitors at the Grand Hotel Europa. Herr Rath, the Oberbürgermeister, presided, and proposed the health of the "King of

Hungary and the Royal Family." This was responded to by Herr Harkányi, member of the Hungarian Chamber, who then proposed "The Queen of England," the band playing "God Save the Queen," amidst the utmost enthusiasm. Herr Bela von Ambrozovits, engineer and councillor at the Department of Means of Communication, proposed "The Members of the Iron and Steel Institute," referring to the thirst for knowlege, spirit of enterprise, and inexhaustible energy manifested by Englishmen, and expressed the pleasure felt by Hungarians at being able to receive so many in their metropolis at one time. Mr. James Kitson acknowledged the toast, and concluded by proposing the "Buda-Pesth Society of Engineers." This toast was acknowledged by A. Ritter von Kerpely, who proposed the "German Members of the Iron and Steel Institute." Speeches were also made by Count Emanuel Andrassy and Count Lónyay (President of the Hungarian Academy of Sciences), who proposed "The French Industry and Nation," responded to by M. Pourcel, of Terre-Noire.

GANZ & CO.'S WORKS.

On Saturday, September 23, the party proceeded by one of the fine steamers built by the Donau Dampschifffahrts Gesellschaft, to inspect the engineering works of Ganz & Co., who have acquired a European reputation for their chilled castings, and who, from first to last, have turned out 461,111 chilled cast iron waggon wheels on the American system. Their other specialties are turbines and Hungarian corn-mills with chilled steel rollers, chilled points and crossings, and ornamental iron castings for building purposes.

The works at Buda were founded in the year 1844 by A. Ganz, a native of Switzerland, and produced until 1854 ordinary castings only. At this time, some far-seeing railway engineers induced Mr. Ganz, whose name had become well known as an excellent founder, to occupy himself with the manufacture of chilled cast iron wheels; and using only Hungarian iron of the best quality, that gentleman was able to produce wheels of remarkable perfection. After these wheels had been adopted experimentally by the administration of the Imperial Austrian Railway, the Southern Railway, &c., the Theiss Railway Company gave to Mr. Ganz, in 1857, a large order for them. The general introduction of these wheels dates from this time, and since then their manufacture has developed until the small foundry has become one of the largest works in the Austro-Hungarian Empire.

After the death of Mr. Ganz in 1867, his heirs associated themselves with the managing directors of the establishment, Messrs. A. Eichleiter, U. Keller, and A. Mechwart, for the continued development of the works.

In 1869, this partnership was transformed into a share company, which still, however, carried on the business under the name of Ganz & Co. The president of the Company is his Excellency M. Paul de Somssich, and the chief director is Mr. A. Mechwart. The Company has a branch establishment at Ratibor in Germany, possesses a blast furnace in Upper Hungary, and special works for the manufacture of wagons.

Another specialty of the Company is the manufacture of crossings or cross pieces of chilled cast iron, which was also commenced by Mr. Ganz about twenty years ago.

A third specialty is the manufacture of projectiles of any calibre, specially those of chilled cast iron; and a fourth is the manufacture of rollers for grinding purposes, from which the milling trade has derived great advantages.

The chilled cast iron wheels made by Ganz & Co. include the most usual patterns for mining, wharf, tramway, and railway traffic. They are cast mainly from Hungarian iron, and they show on their circumference a hard white crust of from 10 to 15 mm. thickness, changing gradually into grey cast iron. With respect to the crossings, the firm has about 300 patterns for different angles and various modes of construction, and are able to answer any requirements.

In a recent year the Company produced about 20,000 cast iron wheels, 1364 crossings, 17 turntables, 1348 roller-mills, and nearly 600 tons of projectiles. It is the custom to use mixtures of Hungarian and English iron in almost equal proportions for some of the castings. The works, however, did not present any features of special novelty to English founders.

THE DANUBE SHIPBUILDING WORKS.

The party next steamed down the Danube to Alt-Ofen, and landed at the shipbuilding works of the Donau Dampschifffahrts Gesellschaft. Here they were received by Herr Ludwig Ullman, director, and by Mr. Murray Jackson, the works manager. These works, established forty years ago, employ from 2000 to 2500 hands, and turn out almost everything connected with iron shipbuilding. They roll rounds and squares, large bars and light sections, as well as angle irons from scrap, chiefly their own. Plates and special sections, however, they do not roll. Specimens of such iron from Hungarian works was shown for the visitors' inspection. There was a Judenberg plate of iron, 16 ft. by 3 ft. by $\frac{5}{32}$ in., and a Neuberg Bessemer steel plate, 14 ft. by 4 ft. by $\frac{1}{8}$ in., weighing 5 lbs. to the square foot. The English dimensions are explained by the fact that the first vessels of the Company were made in England by Penn's, Maudsley's, and other firms; and it was, of course, necessary in renewals to follow the original patterns, &c. There was also iron from Reschitza, Judenberg, Witkowitz, and Dunaberg, some capitally welded iron flue tubes, a channel iron 6 in. by 2½ in. by ½ in., &c.

There were on the stocks six steamers under repair, and seven entirely new in various stages of manufacture. They are all perfectly flat in the bottom and of very slight draught, so as to carry on the navigation of the Danube in all seasons. One of these vessels, the *Baranya,* a paddle-boat, was being entirely refitted with boilers and compound engines. The latter were in the shop at the time of the visit, and were examined by the party. The high-pressure cylinder is 32 in. in diameter, and the low-pressure 50 in., while the stroke is 4 ft. At 39½ revolutions a minute, the indicated horse-power is calculated at 762. The party also examined the *Hildegarde,* fitted with a new type of engines designed by the manager, Mr. Murray Jackson, who has also devised a compound tug and hauling boat, with screw fore and aft, for combining the system of ordinary towing with chain towage. She has been at work on the Danube since June, and gives every satisfaction. Some steel boilers were being completed for the *Kaloca.* Altogether, about sixteen to seventeen new boilers are made yearly, besides repairs. Tweddell's hydraulic riveter is used almost exclusively.

The founders have a special manner of welcoming distinguished visitors, as was shown by two castings commemorating the visits of the King and Queen of Hungary and of Paul Ordody. On the present occasion, as the party entered the foundry, the metal was run into a mould, and presently there appeared in glowing letters in the sand, the words "WELCOME IRON AND STEEL INSTITUTE," with the crossed hammers, signifying, "Gluck auf," or "Good luck," and various typical symbols.

After examining some old Roman baths that were discovered about six years ago on the premises of the Shipbuilding Company, the party saw an exhibition of the efficiency of the Company's fire brigade, and thence proceeded to the *Margarethen Insel* (an island in the centre of the Danube, between Pesth and Buda), where they were entertained to a splendid luncheon by the city authorities, several complimentary toasts being afterwards given.

The next item on the day's programme was an inspection of the locomotive works of the Hungarian State Railways, where the members were again courteously received by the heads of the various departments, and shown the various processes employed in Hungarian locomotive practice.

In the evening the members were invited to a special performance, organised in their honour, in the Volkstheater, of a national piece illustrating Hungarian manners and customs.

On the following morning, some of the members went to the iron-works of Salgó-Tarjan and Diösgyor, three and four hours west of the city, while others proceeded to the Bessemer steel works of Reschitza, in the south-east corner of Hungary.

OBITUARY.

Mr. **William Menelaus**, of Dowlais, died at Tenby, Pembrokeshire, after a long and painful illness, on Thursday, 30th March 1882. He was born in East Lothian, Scotland, 10th March 1818, and after education at a local school, apprenticed to a firm of engineers at Haddington, near Edinburgh. After serving his time, he went to London, where he did not remain long. In 1839 he was at Middlesbrough, erecting—and keeping at work after erection—brickmaking machinery for the Messrs. Pease, who at the time were engaged upon the Middlesbrough Dock. He was afterwards in the service of a company established for the introduction of improved agricultural machinery, and in 1843 was sent by that company to superintend some work at Hensol Castle, Glamorganshire, the seat of the late Mr. Rowland Fothergill, the well-known Welsh ironmaster, who governed the Abernant Ironworks, Aberdare, South Wales, in the days of their prosperity. Mr. Fothergill appreciated the ability of young Menelaus, and offered him the post of assistant engineer at the ironworks, which he accepted. From this beginning, he advanced steadily, became soon chief engineer of the works, and assisted considerably in the extension and improvement of machinery for the manufacture of rails in South Wales.

In 1851 Mr. Rowland Fothergill having retired, Mr. Menelaus left Aberdare and entered the service of the Dowlais Iron Company as engineer, becoming shortly afterwards chief manager of their extensive forges and mills. When Mr. John Evans, the general manager of Dowlais, retired in 1865, Mr. Menelaus took his place, and continued to act as general manager of Dowlais until the time of his death.

Under this guidance of Mr. Menelaus, Dowlais grew very much both in size and standing. When Mr. Bessemer, at the British Association meeting at Cheltenham in 1856, announced his great discovery, Dowlais was prompt to take it up, and made a series of experiments, extending over several months, to test its value, but without practical success. Later on, after Mr. Mushet had shown how, by the addition of spiegeleisen, the main difficulty in the way of the Bessemer process had been removed, steel-making was resumed at Dowlais, and grew to an extent equal to, if not greater than, that at any other existing works. Mr. Menelaus also established at Dowlais the manufacture of steel by the Siemens process, the plant which he erected for that purpose being amongst the first designed to carry on the open-hearth process on a large scale in this country.

Mr. Menelaus was one of the first to attempt puddling by mechanical means. In this direction he strove for many years, and he worked regularly puddling machines, respecting which, in a paper read by him before the Institution of Mechanical Engineers, he admitted that he had not succeeded, although the results obtained were encouraging. The main difficulty was to maintain the fettling, and this the Danks' furnace promised for a time to get over, but unfortunately it did not fulfil that promise. It was at this time becoming more and more evident that iron rails were doomed to replacement by steel, and for this reason, perhaps, the chief puddlers of the country discontinued their efforts, and machine puddling was not persevered in.

When the proposal to form the Iron and Steel Institute was put forward in 1868, Mr. Menelaus was one of the first to co-operate in the scheme; and when the Institute was formally constituted in 1869, he was elected a vice-president. This position he continued to hold until, in 1875, in succession to the Duke of Devonshire, Sir Henry Bessemer, and Mr. I. L. Bell, respectively, he became president of the Institute. His presidential address on that occasion was chiefly devoted to a retrospect and consideration of the position of mechanical puddling, and of the applications and prospects of steel. He has also contributed to the "Proceedings" of the Institute a paper on "Improved Machinery for Rolling Rails,"* describing some improvements which the author during the depression of 1867–68 introduced into the big mill at Dowlais for the purpose of saving labour. Mr. Menelaus was a frequent speaker at the meetings of the Institute, and the high practical value of his criticisms is amply attested by the *Journal* in which they are recorded.

In May 1881, less than a year before his death, Mr. Menelaus was presented with the Bessemer gold medal, in recognition of his services to the iron manufacture.

Mr. Menelaus was a member of the Institution of Civil Engineers, a member and a vice-president from 1870 to 1873 of the Institution of Mechanical Engineers, and a member of the South Wales Institute of

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* Transactions for 1869, p. 187.

Engineers. He was, indeed, a founder of the last-named society, of which, on the 29th October 1857, he was elected first president, while he was re-elected to the presidency in 1864. To the latter Society he contributed, besides his inaugural address as president in 1857, a paper "On Rolling Heavy Iron," which was read at Newport in 1860. His contributions to the Institution of Mechanical Engineers embraced a paper "On the large Blowing Engine and new Rolling Mill at Dowlais Ironworks" * and "On Mechanical Puddling." † The latter subject was one on which he frequently spoke at the meetings of the Iron and Steel Institute, and he acted as Chairman of the Committee established by the Institute to investigate and report upon the merits of the various systems of mechanical puddling.

Than Mr. Menelaus, it is perhaps no exaggeration to say that there was no more indefatigable worker in the manufacture of iron and steel, no one who had more thoroughly mastered it in the best practical way, and few if any who enjoyed at Dowlais and elsewhere a stronger and better reputation.

Sir **Henry W. Ripley**, who died at his residence, Bedstone House, Shropshire, on the 9th November last, was born at Bradford in 1813, and was thus in his seventieth year. His father was Mr. Edward Ripley, of Bowling Lodge, Bradford, where he received his early training. The deceased was head of a large manufacturing firm in Bradford, with which town he had all his life been prominently connected. In general commercial and industrial affairs he took a deep interest, and from 1862 to 1870 he acted as president of the local Chamber of Commerce. He was also a director of various industrial concerns of importance in the West Riding.

At the general election of 1868, the deceased gentleman was returned to Parliament as member for Bradford, but he had only filled that position a few months when he was unseated on petition. He became a candidate again in 1874, and was returned on that occasion as the colleague of the Right Hon. W. E Forster, but at the election of 1880 he was defeated, and from that time he took little part in public affairs. In acknowledgment of his public services, the deceased received the honour of a baronetcy in 1880. He became a member of the Institute in 1876, but he never took any active part in its proceedings.

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* Proceedings, 1857, p. 112.
† Ibid., 1867, p. 151.

Lord **Frederick C. Cavendish** was the second son of the seventh Duke of Devonshire, and was born in 1836. He was educated at Trinity College, Cambridge, where he distinguished himself in mathematics, being senior optime in 1858. The deceased nobleman entered Parliament as member for the West Riding of Yorkshire, and continued to sit for that constituency until his decease. He was private secretary to Lord Granville (Lord President of the Council) from 1859 to 1864, and private secretary to Mr. Gladstone in 1872–73. He was appointed a Junior Lord of the Treasury in 1873, and in 1880, on the accession to power of the present Liberal Government, he became Secretary to the Treasury. That position he continued to hold until May 1882, when, on the resignation of the Right Hon. W. E. Forster, he became Chief Secretary for Ireland.

Lord Frederick was possessed of much greater business capabilities than his generally retiring and unassuming demeanour appeared to indicate. Like his distinguished father, he had for many years taken an active interest in industrial and scientific progress, and especially of the iron and allied trades. More than this, he was actively associated with the development of one of the most important iron-producing districts in the United Kingdom. He was for a number of years, and up to the time of his decease, one of the directors of the Barrow Hematite Iron and Steel Works,—the largest establishment of its kind on the west coast; and in that capacity he acquired an intimate knowledge of the position and prospects of the iron manufacture. He was also a director of the Furness Railway, of which, as well as of the Barrow Steel Company, the Duke of Devonshire has for many years been chairman; and generally, it may be said, that he was associated with his noble father, Sir James Ramsden, Mr. J. T. Smith, and others, in the remarkable development of the town and district of Barrow-in-Furness.

Elected a member of the Iron and Steel Institute in 1869, the deceased nobleman became a member of Council in 1874, and a Vice-President in 1882, only a few weeks before his death. He never took part in any of the discussions, but was a tolerably frequent attender at the meetings of the Institute, and generally evinced an active interest in its proceedings. As a member of Council he attended to his duties with much assiduity, and was frequently intrusted by his colleagues with special missions on behalf of the Institute. Only a fortnight before his death, he was waited upon by the President and Secretary of the Institute, with a view to his arranging for the receipt of the

Bessemer medal by the American Ambassador, on behalf of the family of the late Mr. Holley; and two days before he left on his ill-starred journey to Dublin, he carried out this commission and communicated to the Council of the Institute the results of his interview with Mr. Lowell on the subject.

When the British Iron Trade Association was formed in 1876, Lord Frederick Cavendish at once became a member, and in 1879, in succession to Mr. D. Dale of Darlington, he was elected its President. On this occasion he delivered an address, which, although brief in substance, is still a sufficient evidence of the thoughtful consideration he was accustomed to bestow on the affairs of our great industry. He showed the remarkable statistical development of the trade within recent years, urged the value of free trade despite growing protectionist tendencies abroad, and concluded by a prediction which up to the present time has been fully verified. "Whatever happened," he said, "our exports of iron could not diminish. In this country it was absolutely necessary that, in order to feed our population, we had to import 140 millions worth of food a year. Of this, then, we might be quite certain, that foreigns nations, however anxious they might be to export, would not be ready to give us that supply of food for nothing. And that meant that we must pay for it in some way or other. We must pay for it mainly by our manufactures. And of all manufactures which had a safe and strong position in this country, he would venture to say the iron trade was the strongest and the safest, for it had immense natural advantages. We had an ample supply of capital, we had skilled labour, and we had wonderful enterprise in employers. We had also an unexampled position for shipping, and a mercantile marine which placed us in the most advantageous position for exportation. With these advantages he thought it was absolutely certain that the iron trade must be the last to fall in this country."

During his presidency of the Iron Trade Association, Lord Frederick interested himself very actively in matters relating to foreign tariffs, &c., as to which, from his position as a member of Parliament and his exceptional influence in high quarters, his efforts were calculated to be of great value to the trade, and it was with much regret that his colleagues were compelled to accept his resignation on his appointment to the Secretaryship of the Treasury.

Directly after his appointment to the Chief Secretaryship for Ireland, Lord Frederick proceeded to Dublin with Earl Spencer, the newly-appointed Lord Lieutenant, and on the very evening of his arrival in that city, the 6th of May, he was assassinated in the Phœnix Park, together with Mr. Burke, the Under Secretary, under circumstances that have sent a thrill of horror and indignation throughout the civilised world.

To the character and capacity of the deceased nobleman, testimony has been borne in such exalted quarters that it would be little short of impertinent to add anything to it here. "There are," said Earl Granville, in moving the adjournment of the House of Lords on the occasion of his Lordship's decease, "noble Lords on both sides of the House who are well aware of how distinguished a type he was of the permanent civil servant of this country, especially when placed in a position of great difficulty. I have known intimately, and for many years, Lord Frederick Cavendish, and I have never known a purer or a finer nature. He was absolutely without personal vanity, without any love of display, but with his great ability, his knowledge, and his industry, he only required a difficult position in order to show the metal of which he was made. He was reluctant to leave the office that he filled so well, but, like a soldier, he obeyed without one moment's hesitation the call of duty, to take a position of enormous difficulty. He suffered a miserable death, but one glorious in itself, as he died in the service of his country."

Not less emphatic was the tribute paid by Mr. Gladstone to the memory of the departed nobleman. "One of the very noblest hearts," he said, "has ceased to beat, and has ceased at the very moment when just devoted to the service of Ireland, full of love for that country, full of hope for the future, full of capacity to render her service."

The remains of Lord Frederick Cavendish were removed to Chatsworth House, Derbyshire, for interment, and the Council of the Institute, having regard to the altogether exceptional character of the occasion, adjourned the general meeting over the day of the funeral, and adopted a special vote of condolence with the Duke of Devonshire and the other members of the family of the deceased.*

ALEXANDER LYMAN HOLLEY was born on July 20, 1832, at Lakeville, Salisbury, Conn., of which State his father, Alexander H. Holley, was subsequently Governor. After some years' schooling at the academy of his native county, he went to another school at Stocksbridge, Mass., whence he was transferred in course of time to Brown University at Providence. At an early age he showed an aptitude for mechanics. In his seventeenth year he wrote that he had been devoting all his leisure time for nearly two weeks "in making sectional and perspective views of the internal works, machinery, steam-works, &c., of the most improved locomotive engines, showing how the steam is made, applied, and cut off at half stroke or not, and how the engine is worked every way, in some seventeen different pictures, with explanations filling some eight or ten pages." When eighteen years of age, Holley, still at Stocksbridge, is found writing treatises on gun-cotton and on the manufacture of pocket cutlery, the latter of which was published in Poor's *Railway Journal* during the summer of 1850. A writer in the *American Machinist* of March 8, 1882, speaking of Holley at this period, states that "during one of his vacations he came up from his Salisbury home expressly to show me a miniature engine of his own building. It was complete in all respects, of skilful workmanship, and on being fired up, ran with admirable success. Thus he foreshadowed his devotion to the mechanic arts which so eminently characterised his manhood." In 1852 Holley invented a new cut-off, of which he wrote, "It is bound to be patented, if I sell the coat on my back to pay for it, and go without any. I have shown my plans to a man who was four years with Messrs. Corliss & Nightingale of this place (Providence). These men have invented and are making the most improved cut-off engine of the day, and this gentleman says that my engine (that is to be) embraces all its improvements and none of its disadvantages." This cut-off, although never patented, was illustrated and described in the *Mechanical Magazine* in July 1852. It is a detached escapement, working both directly by a cam (at the end of the stroke), and indirectly from the governor at any point during the stroke. While still at college, Holley wrote a treatise on "Water Considered as a Carrier," which was published in 1854 in the *Litchfield Inquirer*, and which deals at considerable length with such matters as the functions and properties of water as a conveyer of gases, mechanical sediments, dissolved salts, germs, &c., and of its agency in geological formations, volcanic eruptions, and so on. Graduated in September 1853 with the degree of Bachelor of Philosophy, Holley's discourse on this occasion referred to the "Natural Motors," and embraced descriptions of different kinds of engines, including Ericsson's caloric.

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* *Journal*, No. I., 1881, p. 10.

His college career having terminated, Holley entered the employment of Messrs. Corliss & Nightingale at Providence, where he served both as draughtsman and machinist in the locomotive department.

While so occupied, his efforts were directed to the attempt to apply to the locomotive engine the principle of the variable cut-off, for which purpose he ran the "advance" locomotive for some time on the Stonington Railway. His experiences with this locomotive, which was nicknamed the "Old Jigger," were described by Holley with characteristic humour in May 1881. "It had," he said, "as nearly as I can remember, 365 valves, one to break down every day in the year; and as to valve motion, well, nobody ever counted the number of its pieces. They were as the sands of the sea shore. Most of them used to jar off the first few trips of the week." Neither Holley nor his employers seem to have succeeded in applying successfully to the locomotive engine the detached variable cut-off, and another arrangement was ultimately substituted.

In March 1855 Holley left the works of Corliss & Nightingale to seek for other employment. With this object he visited the principal locomotive shops in the far West, including Cleveland, Detroit, Cincinnati, Covington, Louisville, Chicago, and St. Louis. For a time his efforts were singularly unsuccessful. "It is strange," he says in a letter of this date, "that when I have taken such pains to present myself modestly, and am willing to do anything, and work and persevere to the utmost extent; when I have got such strong letters; and when I know that I can build a better locomotive than all the rest of them put together—even in the face of all this, I cannot, in the whole Western country, get a place to earn my daily bread." Ultimately the young man obtained a subordinate engagement at the locomotive works in Jersey City, which, not affording sufficient scope for his energies, he left to follow the career of a technical journalist.

Beginning as a contributor to Zerah Colburn's *Railroad Advocate*, Holley in 1855 became co-proprietor and editor of that paper. In 1856 Colburn relinquished his interest in this venture entirely to Holley, who continued for another year to publish it as *Holley's Railroad Advocate*. In July 1857 Colburn again joined Holley in the publication and control of the *American Engineer*, in which the *Advocate* then became merged, but in neither form was the journal a commercial success, and in September 1857 it finally ceased to exist. Holley and Colburn soon afterwards undertook a journey to Europe to study railway practice and report thereon for the benefit of several American railway companies, on whose behalf they held a commission. In 1858 their report appeared under the title "The Permanent Way and Coal-burning and Locomotive Boilers of European Railways, with a

Comparison of the Working Economy of European and American Lines, and the Principles upon which Improvement must Proceed." Returning to America, Holley for a time supported himself mainly by his pen, his contributions chiefly appearing in the *New York Times*, where Mr. R. W. Raymond (*Memorial Address*, November 1, 1882) has found two hundred and seventy-six articles from his pen, of which about two hundred appeared between 1858 and 1863, and the remainder at rarer intervals until the last, which was the leading editorial of April 27, 1875, and dealt with the United States Testing Board. An analysis of these articles indicates the range of Holley's acquirements. Forty-nine were devoted to railways, forty-two to steam navigation, twenty-two to the Stevens battery, nineteen to arms and ordnance, eleven to boiler explosions, seven to steam-engines, thirty to general engineering topics, and fifty-two to political, social, and other subjects.

In 1859 Holley accompanied H. J. Raymond of the *New York Times* to Europe, as correspondent of that journal. In that capacity he wrote a number of articles descriptive of the *Great Eastern* steamship. In 1860 he became editor of the mechanical department of the *American Railway Review*, and continued to act in that capacity for about eighteen months. In 1860 he published his "American and European Railway Practice." In March 1861 he arranged to supply engineering articles and definitions to "Webster's Unabridged Dictionary." In 1864 his treatise on "Ordnance and Armour" appeared, and about the same time he published many articles in popular and scientific reviews on iron-clad ships and heavy ordnance.

In 1863 Holley was employed by Corning, Winslow, & Co. to inquire into the Bessemer steel manufacture, which had then begun to attract some attention on the other side of the Atlantic Proceeding to England for that purpose, Holley was successful in effecting the purchase of the Bessemer patents for his employers, and subsequently aided in their combination with the conflicting American patents of Kelly. In 1865 he designed and constructed the works of Troy, the first Bessemer steelworks erected in the United States. In 1867 he enlarged the Troy works and built those at Harrisburg. Subsequently he planned the Bessemer works of North Chicago and Joliet, the Edgar-Thomson Works at Pittsburg, and the Vulcan Works at St. Louis, while he also acted as consulting engineer in designing the works of Cambria, Scranton, and Bethlehem. The improvements which Holley from time to time introduced into Bessemer plant and practice have been thus summarised by R. W. Hunt in his paper on the "History of the Bessemer Manufacture in America:"—*

"The result of his thought gave us the present accepted type of American Bessemer plant. He did away with the English deep pit, and raised the vessels so as to get working space under them on the ground-floor. He substituted top-supported hydraulic cranes for the more expensive counter-weighted English ones, and put three ingot cranes around the pit instead of two, thereby obtaining greater area of power. He changed the location of the vessels as related to the pit and melting-house. He modified the ladle crane, and worked all the cranes and the vessels from a single point. He substituted cupolas for reverberatory furnaces; and last, but by no means least, he introduced the intermediate or accumulating ladle, which is placed on scales, and thus ensured economy of operation by rendering possible the weighing of each charge of melted iron before pouring into the converter. These points cover the radical features of his innovations. After building such a plant, he began to meet the difficulties of details in manufacture, among the most serious of which was the short duration of the vessel bottoms, and the time required to cool off the vessels to a point at which it was possible for workmen to enter and make new bottoms. After many experiments, the result was the Holley converter bottom, which, either in its form as patented, or in a modification of it as now used in all American works, has rendered possible, as much as any other one thing, the present immense production. Then he tried many forms of cupolas at Troy, adopting in the original plant a changeable bottom and section below the tuyeres, and developing this idea still further in the first five-ton works. Later, at Harrisburg, the furnace was improved to a point which rendered these many bottoms unnecessary, chiefly by deepening the bottom and enlarging the tuyere area. Upon his rebuilding the Troy Works after their destruction by fire, Mr. Holley put in the perfected cupolas. At this time, the practice was to run a cupola for a turn's melting, which had reached eight heats or forty tons of steel, and then dropping its bottom. This was already an increase of 100 tons of steel over his boast about the same amount in twenty-four hours." †

Mr. Holley did not, however, limit his professional work during the later and most active years of his life to the Bessemer steel manufacture.

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* Transactions, American Institute of Mining Engineers, vol. v. p. 201.

† The effects of Mr. Holley's improvements in Bessemer works and practice are also referred to in Captain Jones's paper on "The Manufacture of Bessemer Steel and Steel Rails in the United States," in the *Journal*, No. I., 1881, p. 129.

He was scarcely less active in assisting the development of the open-hearth steel trade, and it is due to him that the Pernot furnace and the Krupp washing process became established in the United States. It was he, also, who negotiated the purchase by the Bessemer Steel Association of the patents relating to the basic Bessemer process.

As an inventor and patentee, Holley achieved a considerable amount of success. He obtained sixteen patents in all, two of which, taken out in 1859, were for a variable cut-off valve for steam-engines, and another for railway chairs. Ten other patents refer to improvements in the Bessemer process and plant, two to roll-trains and their feed-tables, while the remaining two are for a water-cooled furnace roof, and for a steam-boiler furnace with gaseous fuel, respectively. The last of his Bessemer patents relating to a detachable converter shell,* as now applied at Seraing, Witkowitz, and other works, has been purchased since his death by the American Bessemer Association. This, and the converter bottom,† patented 9th August 1870, are regarded as his most important contributions to Bessemer practice.

Space will not allow us to add much that is left unsaid. In January 1869 Holley became first editor of Van Nostrand's *Eclectic Engineering Magazine*, a position which he held for over a year. In 1865 he became a member of the Board of Trustees of the Rensselaer Polytechnic Institute, where he made his influence felt in favour of an improved curriculum. In 1876 he was one of the jurors on iron and steel, and contributed to the "Reports of the Judges of the Centennial Exposition" the paper on that subject. In 1880 he published in *Appleton's Cyclopædia of Mechanics* an able treatise on steel; and from 1877 to 1880 he published in *Engineering* a series of illustrated articles on American iron and steel works which have been much appreciated in Europe. In 1875 he was appointed a member of the United States Board for testing structural materials, and in 1879 he became lecturer on metallurgy at the School of Mines in Columbia College.

With social qualities of the highest order, and with a ready talent for debate and for the clear and effective elucidation of any subject which he undertook to explain, it was only natural that Mr. Holley should take a leading part in societies representing applied science on both sides of the Atlantic. He was one of the founders of the American Institute of Mining Engineers, which, established in 1871, has now a membership of nearly 1200, and of which in 1875 he was elected President. In the following year he was elected a Vice-President of the American Institute of Civil Engineers. In 1879, in conjunction with Professor Thurston and other leading engineers, he founded the American Institute of Mechanical Engineers, of which he was elected the first President. He became a member of the Iron and Steel Institute in 1873, and of the Institution of Civil Engineers in 1877. Before these various Societies he read many papers on metallurgical and engineering subjects, every one of which attests the thorough mastery which he had acquired in his profession. Most of his contributions, however, have gone to enrich the Proceedings of the American Institute of Mining Engineers, including papers on—

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* *Journal of the Iron and Steel Institute*, No. II., 1880, p. 714.

† Ibid., 1874, p. 368.

"Three-High Rolls."
"Setting Bessemer Converter Bottoms."
"General Improvements in Bessemer Plant."
"On the Strength of Wrought Iron as affected by its Composition and Reduction by Rolling."
"Notes on Salisbury Iron Mines and Works."
"The Pernot Furnace."
"The United States Testing-Machines at Watertown Arsenal."
"The Tessié Gas Producer."
"Washing Phosphoric Pig Iron for the Open-Hearth and Puddling Processes at Krupp's Works, Essen."
"Notes on the Siemens Direct Process."*
"On the Use of Natural Gas for Puddling and Heating at Leechburg, Pennsylvania."
"What is Steel?"
"Bessemer Plant for the Basic Process."†
"Rail Patterns."‡

Before the same Society, Holley delivered two presidential addresses, the first in February 1876, "On the Inadequate Union of Engineering Science and Art," and the other in the same year "On Some Pressing Needs of our Iron and Steel Manufactures." Before the American Society of Civil Engineers he read, in 1875, a paper "On the Wear of Rails;" and in 1881, to the new Society of Mechanical Engineers, he contributed a paper "On Rail Sections." To the Institution of Civil Engineers Mr. Holley contributed one paper "On the Chemical and Physical Analyses of Phosphoric Steel," and to the Iron and

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* *Journal of the Iron and Steel Institute*, No. I., 1880, p. 270.
† Ibid., No. II., 1880, p. 714. ‡ Ibid., No. I., 1881, p. 285.

Steel Institute two on "Setting Bessemer Converter Bottoms"* and "American Rolling Mills" respectively; besides which he attended and took part in discussions at the Barrow, Paris, and two London meetings of the Institute. In acknowledgment of his eminent services to metallurgical science, the Council of the Iron and Steel Institute forwarded to his family, through the American Ambassador in London, the Bessemer medal for 1882.

In 1880, Mr. Holley, on his usual annual visit to Europe, was seized with an illness which had been threatened by overwork some time before, but the buoyancy and cheerfulness of his own spirits, united to the care and solicitude of his friend Mr. James Dredge, at whose house he lay for weeks almost at the point of death, enabled him so far to recover that he was able in October of the same year to return to New York. In August 1881 he again returned to Europe, and was again seized with illness while on the Continent, but recovered sufficiently to take a part in the October meeting of the Institute in London, and at the banquet given by the Lord Mayor at the Mansion House in honour of the Institute, he made a characteristically happy and appropriate speech in responding for the United States. It was his last public appearance. Indisposition confined him to his room in London for weeks afterwards, but on the 28th December he sailed for his home in Brooklyn, where he died on Sunday, January 27. His funeral took place on February 1, and was conducted by the Rev. H. W. Beecher, who delivered an eloquent memorial address, which with that subsequently delivered by his friend Mr. R. W. Raymond,† and other details relating to his life and work, it is intended to publish shortly in the "Holley Memorial Volume." Since Mr. Holley's death, the Societies with which he was connected and the industry he did so much to promote have taken steps to erect a monument to his memory in the Central Park, New York.

Of Mr. Holley's many-sided character, apart from his career as an engineer and metallurgist, the scope of this too brief sketch does not allow of much being said. The universal esteem in which he was held has been sufficiently evidenced by the manifold tributes of sorrow and regard which have been paid to his memory since his decease by the leading men of the iron trade on the two continents between which his genius and his amiability tended so greatly to establish an *entente cordiale*.

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* *Journal of the Iron and Steel Institute*, No. II., 1874, p. 368.

† "Memorial Address," delivered before a joint meeting of the American Institutes of Civil, Mechanical, and Mining Engineers, November 1, 1882.

Mr. THOMAS AVELING was born at Elm, in Cambridgeshire, on the 11th of September 1824. His family was one of the oldest in Cambridgeshire, in which county it had been settled between four and five centuries. His grandfather was High Sheriff for Cambridgeshire and Huntingdonshire in 1802. Mr. Aveling's father died while he was very young, and his mother subsequently removed to Rochester, where she was married a second time to the Rev. John D'Urban, who for more than twenty years was in clerical charge of the parish of Hoo-Saint, Werburgh. It was in the Hundred of Hoo that Mr. Aveling first gained practical experience in agriculture, and later on he became a farmer at Ruckinge, in the Weald of Kent.

Mr. Aveling was impressed with the fact that a great deal remained to be done to adapt steam-power thoroughly to agricultural requirements. This led him to give up farming and establish small works at Rochester for the manufacture and repair of agricultural implements. One of the points to which he early devoted his attention was that of rendering agricultural engines self-moving. In 1859 he took out a patent for an arrangement of pitch-chain gearing applicable to such engines. He did not at first build engines himself, but applied this gear to ordinary portables, constructed by Messrs. Clayton & Shuttleworth. Later on, however, he commenced engine-building on his own account, and in 1860 he exhibited the first of these engines at the Royal Agricultural Society's Show at Canterbury; while in 1862 his firm exhibited an engine at the London International Exhibition. Later on, the firm of Aveling & Porter took up the manufacture of traction engines for haulage purposes, as well as that of steam-ploughing engines, their works steadily developing in size and productive power until they took rank among the largest in the country.

In Mr. Aveling's earlier engines the power was transmitted from the second motion shaft to the driving axle by a pitch chain. For many years he was not only a strong advocate for this form of gear, but did much to perfect its manufacture. Thus by the employment of a duplex drilling machine to ensure accuracy in the pitch of the links, the use of core annealed steel for the pins, and by the choice of good proportions, he secured for this chain gear a durability far beyond that which it possessed before he introduced his improvements. He also devised convenient arrangements for tightening the chain when stretched, by moving the bearings of the second motion shaft, at the same time maintaining a constant distance between that shaft and the crankshaft, so as not to interfere with the action of the toothed gear. The introduction of steel castings and cast steel gear may, however, be said to have revolutionised traction engine construction, and it led Mr. Aveling to abandon the chain gear entirely for all ordinary engines.

Upwards of twenty years ago, Mr. Aveling patented his well-known arrangement in which an engine cylinder is surrounded by a capacious jacket, forming the steam dome—the steam traversing this jacket on its way to the valve-chest, which it enters at the top. This arrangement is now almost universally adopted by traction-engine builders. It is to Mr. Aveling, also, that the general adoption of single cylinders for traction purposes is due. He is said, indeed, to have been the first to build a traction engine with a single cylinder, and for many years he had to uphold the advantages of that arrangement against great opposition.

A novel arrangement of steering wheel was devised by Mr. Aveling about 1860, and was fitted to the engine exhibited by his firm in the International Exhibition of 1862. According to this plan, which was for many years adopted by the firm to the exclusion of other arrangements, the leading axle had attached to it a light frame projecting forwards, and carrying at its front end the vertical axis of a forked spindle, in the fork of which a sharp-edged wheel was mounted and bore on the road. This wheel could be readily diverted by a tiller to either side, and when thus diverted, it led off to the side towards which it was pointed, taking with it the front end of the light frame, and so locking round the leading axle. The engine thus followed what may be called the pilot-wheel.

Mr. Aveling's later improvements in traction engines include the plan of carrying up the side plates of the fire-box casing to form the brackets for the crank-shaft and counter-shaft bearings, and in steam-ploughing engines for working on the double-engine system, the introduction of right and left hand engines, so as to secure that the rope, when hauling, should in both engines lead on to the side of the drum next the driving pinion, thus relieving the drum-spindle of the greater part of the strain. Mr. Aveling also did much to bring into successful use the combination of a traction engine and crane—an arrangement which he first exhibited at the Royal Agricultural Society's Show at Oxford in 1870, and one which materially increased the usefulness of traction engines.

It has been asserted that, up to the time of his death, no man living had so extensive a practical knowledge of steam haulage on roads as Mr. Aveling, or so thorough an appreciation of the requirements which traction engines ought to fulfil. Of the success which attended his efforts in this direction, the enormous number of traction engines now in use in Kent alone is a sufficient proof, including the numerous military engines (adapted for either rail or road service) which he constructed for the use of the Royal Engineers at Chatham, and on the perfection of which he bestowed much attention.

Mr. Aveling was prominently connected with the introduction of road-rolling by steam. The idea of employing steam power for this purpose originated with the late Mr. William Clark, when chief engineer to the municipality of Calcutta, and a steam road-roller was designed for Mr. Clark by Mr. Batho, then of Birmingham. It was not, however, until the construction of such rollers was taken up by Messrs. Aveling & Porter that they came into use in this country. Mr. Aveling introduced successive improvements from time to time, as experience showed the weak points of the earlier designs, and soon appreciated the serious objections which existed to the employment of the very heavy rollers at first thought to be necessary, applying himself thereupon to the perfection of machines of comparatively light weight, and capable of being readily handled in any thoroughfare. In his traction engines, Mr. Aveling had obtained a very economical motor, and by combining this with the parts requisite for road-rolling, he produced a machine which would do the work at an exceedingly moderate cost for fuel and maintenance. As a result, Messrs. Aveling & Porter's steam road-rollers are now to be found in nearly every important town in the kingdom.

Mr. Aveling was elected an Associate of the Institution of Civil Engineers in 1871, and a member of the same body in 1877. In 1869 he was elected a member of the Institution of Mechanical Engineers, and in 1879 he became a member of the Iron and Steel Institute. About two years ago, he was elected a member of Council of the Royal Agricultural Society, and from the time of his election to that of his decease he took an active part in the management of the Society. In the various International Exhibitions of England, France, Austria, America, and other countries, Mr. Aveling also took an active part, and he received from the French Government the investiture of the Order of Chevalier of the Legion of Honour, while the Emperor of Austria conferred on him the knighthood of the

Order of SS. Francis and Joseph. He was a member of the executive committee of the Peasant Farmers' Seed Fund in 1871, after the Franco-German war.

Mr. Aveling was married to the daughter of Mr. Robert Lake of Milton Chapel, near Canterbury, with whom he learned the business of farming, and in partnership with whom he ultimately established the business of agricultural engineer. He died on the 7th March last from acute inflammation of the lungs, brought on by a cold contracted when yachting in February. Since his decease, a movement has been set on foot in his own town of Rochester to erect a memorial to his memory. The Council of the Farmers' Alliance, of which he was an active friend, and the Council of the Royal Agricultural Society have, since his death, recorded their deep sense of his loss, the President of the latter remarking, that "had it not been for the assistance given by Mr. Aveling to the Chemical Committee, I believe that the improvements made in the chemical laboratory and the reduction of the fees for analysis would not have been carried out."

William Newmarch was born at Thirsk, Yorkshire, on the 28th January 1820, and died at Torquay, on Thursday, the 23d March 1882. Commencing his career as a clerk in the house of Messrs. Leatham, Tew, & Co. of Wakefield, he subsequently joined the staff of the Agra Bank. Concurrently with his employment in these spheres of work, he was a regular contributor to the *Morning Chronicle* and other journals of that day.

His knowledge of the principles of banking and of business generally soon gained for Mr. Newmarch the steady and influential support of the most distinguished City men, and especially of Mr. William Tooke, Alderman Thompson, M.P., and the late Lord Wolverton. Under the advice of these friends, Mr. Newmarch, in 1851, quitted his position at the Agra Bank for the secretaryship of the Globe Insurance Company. Mr. Tooke was then desirous of continuing his book on the "History of Prices, and of the State of the Circulation from 1792;" and Mr. Newmarch co-operated with him in writing two volumes as a continuation of that work. Mr. Newmarch rendered good service to the community by the sound evidence he gave as a witness before various parliamentary committees on currency matters, income tax, &c. Long associated with the Statistical Society of London as one of its honorary secretaries, he took the utmost possible interest in its meetings, and long discharged the duties of editor of its journal. In 1869–71 he was elected to the presidentship of the Society, in succession to Mr. Gladstone. He was also for many years secretary, and one of the most active members of the Political Economy Club and of the Adam Smith Club, now dissolved.

In 1862, Mr. Newmarch quitted the service of the Globe Insurance Company, and accepted a managerial position in the banking-house of Messrs. Glyn, Mills, & Co., where he remained until 1881, when his constitution, never very robust, gave way under a stroke of paralysis. Since then he had rallied to some extent, so that his family had hopes of his recovery, and he was still able to retain a directorship of the Grand Trunk Railway Company of Canada, and a trusteeship of the Globe Million Fund. It was his intention to devote some of the leisure of his retirement to bringing his "History of Prices" down to the present date, had he been spared to do so.

Mr. Newmarch for more than thirty years contributed some of his best work to the public press; in the earlier part of his career to the *Morning Chronicle*, and afterwards chiefly to the *Economist*. In 1853, the *Morning Chronicle* published a series of his papers on the new supplies of gold, which attracted much notice. Reprinted in London in 1853, in a volume of 122 pages, these papers attained a further publicity, and were enriched by some additional chapters, containing an analysis of the Bank of England circulation, to which the then Governor, Mr. J. S. Hubbard, contributed some materials, including valuable notes upon the gold coinage, and on the quantity of English gold coin derived from the melting of American coin.

In 1855, Mr. Newmarch published an interesting essay "On the Loans raised by Mr. Pitt during the First French War, 1793–1801, with some Statements in Defence of the Methods of Funding Employed." The arguments in this essay were supported by very elaborate calculations respecting each of the loans, in which Mr. Newmarch had the co-operation of Mr. Frederick Hendriks, at that time actuary of the Globe Insurance Company.

In 1857–59, Mr. Newmarch read two elaborate papers to the Statistical Society on the "Electoral Statistics of the Counties and Boroughs in England and Wales during the Twenty-five Years that have passed since the Reform Act of 1832." In 1859 he published anonymously a pamphlet entitled "Political Perils in 1859," which contains a defence of Lord Derby's Government on the question of political reform. In 1861, he presided over the Section of Economic Science and Statistics at the meeting of the British Association at Manchester.

Since the death of Mr. Newmarch, the Council of the Statistical Society have arranged for a "Newmarch Memorial Essay," to bear the title, "On the Extent to which Recent Legislation is in accordance with, or deviates from, the True Principles of Economic Science, and showing the Permanent Effects which may be expected to arise from such Legislation."

To his many other business occupations, Mr. Newmarch added that of Director of Palmer's Iron and Shipbuilding Company, a position that afforded him an intimate acquaintance with the affairs of the iron trade, in which he always took a deep interest. On the formation of the British Iron Trade Association in 1875, it was joined by Mr. Newmarch, who was unanimously elected its first Treasurer, a position which he continued to hold until he was succeeded in 1880 by Mr. David Dale. Mr. Newmarch became a member of the Iron and Steel Institute in 1871, but he never took any active part in its proceedings.

Mr. JOHN TREVOR BARKLEY was born at Yetminster, Dorsetshire, on the 12th of October 1826. He was educated at Uppingham School, and began his business career at the South Hetton Collieries, near Sunderland, in 1839, being then thirteen years of age. After assisting for some time in the engineering management of these and other collieries, he began to take an interest in railway business, which was at that time a comparatively new sphere of labour, and in which better prospects of success were opened out to a capable engineer than perhaps any other. Mr. Barkley's first railway appointment was that of resident engineer on the Whitehaven and Furness line, but he was afterwards connected with several others.

In 1850, Mr. Barkley accepted an appointment to manage the coal-mines of Heraclea in Turkey, which were then being developed by the Turkish Government. During the Crimean War the English Government obtained possession of this coalfield, and shared the benefits derived from it with its French allies. Under Mr. Barkley's direction, tramways were laid along the valleys, and smaller tramways laid in many of the mines. Quays for shipping the coal were built, and by regular payments to the workmen great activity was developed and satisfactory results obtained. When the English Government asked for the use of the coalfields, the Turkish Minister refused to grant it, on the ground that it was the private property of the Sultan. Lord Stratford de Redcliffe was, however, then the ambassador of England at the Porte. He sought and obtained an interview with Abdul Medjid, and obtained what he wished, but, as his Lordship subsequently stated, "it was not till after a personal altercation with the Sultan."

Coal can only be shipped from these mines in quite calm weather, *i.e.*, almost exclusively during the summer months. The coast is very bold and exposed, so that the cost of making a harbour or harbours would be very great. There are no headlands of which advantage could be taken, and the water is deep close up to the shore. The mountains surrounding the mines for twenty miles, make it practically impossible to connect the coal workings with any place by a railway. The greatest quantity of coal extracted from the mines in any one year has not exceeded 120,000 tons. It nominally costs the Government 16s. a ton delivered in Constantinople; it really costs considerably more.

The Heraclea mines, under these circumstances, never did much good as a commercial enterprise. Although the coal is of good quality and worked by adits and levels in seams of 10 to 16 feet thick, the difficulty of transporting it to suitable markets, and the competition offered by English coal, brought in many cases to Constantinople as ballast in grain-carrying ships—making coal almost as cheap there as in London—affected the success of the enterprise; and after four or five years, Mr. Barkley gave it up. In 1855, he returned again to railway engineering, and engaged in the construction of the Danube and Black Sea Railway, a line forty miles in length, which was pioneered by Sir Samuel Cunard, Mr. Price, now a member of the Railway Commission, and other English engineers and capitalists of position.* Several other railways in the east of Europe were constructed by Mr. Barkley—including the Rustchuk and Varna line—as well as upwards of twenty bridges in Roumania, &c., chiefly on the Bucharest and Varna Railway. Falling into indifferent health, Mr. Barkley, about 1869, returned to England, where, however, his active and vigorous mind did not brook a long period of idleness. He took an active part in several commercial and engineering undertakings, and on the formation, in 1872, of the Landore Siemens-Steel Company, he became, with Mr. Dillwyn, M.P., and Dr. Siemens, one of its first directors. He took an active interest in the development of the steel manufacture by the Siemens process, with the details of which he was thoroughly acquainted. He was elected a member of the Iron and Steel Institute in 1873. He died on the 8th of January last, in the fifty-seventh year of his age.

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* This railway, after having been carried on for a number of years as a private undertaking, was sold in November, 1882, to the Roumanian Government.

Mr. C. P. STEWART, who died at his Berkshire residence, Suninghill, on Tuesday, July 7th, was the senior member of the firm of Sharp, Stewart, & Co., of the Atlas Works, Manchester, and commenced his career in that city as a merchant and engineer.

The above-named firm, with which the late Mr. Stewart had been so long connected, was established about half a century ago by Thomas Sharp, an iron merchant, and Richard Roberts, well known not only for his invention of the self-acting mule, but for the production of many ingenious self-acting tools. At first the business of the firm was chiefly that of machinists, carried on at the Faulkner Street Works, but subsequently locomotive building was introduced, and the new works, subsequently so well and widely known as the Atlas Works, were erected. This was followed by a division of the concern, Mr. Roberts taking into partnership Messrs. Fothergill and Robinson, and carrying on the machine-making at the old works, while the locomotive building branch was carried on at the new works, under the style of Sharp Brothers. About the year 1852, Mr. Stewart was admitted a partner, when the style of the firm became Sharp, Stewart, & Co., by which it has since been known. A few years later, by the retirement from the firm of the brothers Sharp, the concern came into the hands of Mr. Stewart and Mr. Robinson, and in 1864 was formed into a limited company, with Mr. Stewart as chairman, a position which he held until his death.

Messrs. Sharp, Stewart, & Co. usually employ from 1200 to 1300 hands at their Atlas Works, and are known chiefly as builders of locomotives, with the gradual development and improvement in the construction of which Mr. Stewart has been prominently identified.

Mr. Stewart was mainly instrumental in introducing to the steam users of this country the Giffard * injector, which was brought out in 1859, the advantages of which so struck him whilst travelling abroad, that he made arrangements for bringing it over to England, where, as is already known, it was speedily so largely adopted as to fully justify Mr. Stewart's conclusions as to the value of the discovery.

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* It may be noted that M. Giffard died in April last, in the fifty-eighth year of his age.

Mr. Stewart became a member of the Iron and Steel Institute in 1869, but he never spoke at any of its meetings. He had also been a member of the Institution of Mechanical Engineers since 1859, and contributed to that Society one paper on "Seller's screwing machine."*

Mr. **CHARLES SMITH** was a native of Arbroath, in Forfarshire, and was born on September 5, 1843. When sixteen years of age, he was apprenticed to Messrs. Randolph, Elder, & Co., engineers, Glasgow, and about three years later was taken into the drawing-office, where he soon took the position of one of the leading draughtsmen. After completing his apprenticeship, he was appointed chief draughtsman to Messrs. James Howden & Co., Glasgow, and about five months later he became chief draughtsman at Messrs. Randolph, Elder, & Co.'s Works in Glasgow, being then only twenty-one years of age.

In 1870, when in his twenty-seventh year, he succeeded Mr. G. W. Jaffrey as manager at the Engineering and Shipbuilding Works of Messrs. T. Richardson & Sons, Hartlepool, in which firm he became a partner seven years later. He was a strong advocate of the compound type of engines, and also of the double-ended class of marine boilers. He introduced numerous improvements in matters of detail, and earned for the work produced at Hartlepool a high reputation.

Mr. Smith was a member of the Iron and Steel Institute, of the Council of the Cleveland Institution of Engineers, and of the Institution of Mechanical Engineers. He was only in his thirty-ninth year when he died suddenly at Lucerne on the 12th June last.

WILLIAM SARGEANT RODEN was born at Wolverhampton in 1829, and was educated at Bristol, after which he was placed with his uncle, the late Mr. Thomas Brown, at the Ebbw Vale Ironworks, in South Wales. In 1857, he joined the Shelton Bar Iron Company and became the managing partner. Under his management, which continued until about eight years ago, very extensive additions were made to the Company's works, and the large ironworks at Etruria, which are amongst the finest in Staffordshire, were erected under his personal supervision.

Soon after his connection with the Potteries, Mr. Roden manifested an interest in public matters, and took an active part in the formation of the Hanley Rifle Volunteer Corps in 1859. In 1871 he became Hon. Colonel of the Staffordshire and Shropshire Artillery Volunteers.

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* *Proceedings*, 1861, p. 231.

He also identified himself with the municipal life of the borough of Hanley, becoming a member of the Town Council in 1863. He served the office of Mayor from 1866 to 1868.

Soon after Mr. Roden came into the district in 1857 there was a parliamentary election, when he took an active part in promoting the return of Mr. Ricardo and Mr. Gower for Stoke-upon-Trent; and for many years he was an ardent and powerful supporter of Liberal candidates for that borough. In November 1868, a general election took place, and Colonel Roden was elected, with Mr. Melly, without opposition to represent Stoke-upon-Trent. While he was an attentive member generally, he devoted special attention to the wishes of his constituents, and his persistent efforts, in conjunction with the present Lord Norton and Mr. Melly, largely contributed to the rejection of the Trent Purification Bill, which was at that time regarded as inimical to the interest of the Potteries district. At the dissolution in 1874, Mr. Melly and Colonel Roden were again candidates for the representation of Stoke, but through the split occasioned by the candidature of Mr. Walton, the latter was defeated.

Colonel Roden was a J.P. and D.L. of the county of Stafford, and J.P. for the county of Monmouth and the borough of Hanley. He married in 1860 Theodora, daughter of Mr. Samuel Butcher, of Sheffield, who died in February 1867, leaving one son, now nineteen years of age.

Colonel Roden was an original member of the Iron and Steel Institute, and in 1871 was elected a member of the Council. He died at his residence in Paddington on the 25th April 1882.

Mr. **William Neilson** was born in the early part of the year 1810, and died on Wednesday, May 24, 1882, being thus at the time of his decease in the seventy-third year of his age. His grandfather, Walter Neilson, was associated with William Dixon of the Govan Ironworks, and his father was John Neilson of Oakbank Engine Works, Glasgow. An uncle of the deceased was James Beaumont Neilson, the well-known inventor of the hotblast as applied to iron smelting. Walter Neilson, his eldest brother, who survives him, was one of the founders of the well-known Summerlee Ironworks in the year 1837.

Along with his brother Walter, the deceased was actively trained by his father at the Oakbank Engine Works in all the branches of mechanical engineering, as that art was then pursued, including boilermaking, smithwork, millwright work, &c. Partly from the fact, no doubt, of Mr. J. Beaumont Neilson being appointed to the manage- of the first Glasgow gaslight works, a considerable amount of business came to the Oakbank Works in connection with the equipment of some of the earliest gasworks established in Scotland, including those of Glasgow, Dundee, Kilmarnock, Arbroath, and Johnstone. Colliery machinery formed at first the principal part of the work done at the Oakbank establishment, but as the two sons, Walter and William (the deceased), came to take an active part in its management, a much higher class of engine work was manufactured Heavy pumping and winding engines were turned out at Oakbank, as well as condensing engines for mills and other works, while in a number of instances some excellent types of blowing engines were made by the firm, including No. 1 and No. 2 engines at Summerlee Ironworks, and another for the Nibshill Ironworks. The firm also made a number of marine engines for Clyde and Channel steamers. At the same works the *Fairy Queen*, the first iron steamboat that ever sailed on the Clyde, was constructed. After its construction, this vessel had to be hauled from the works to the Clyde, a distance of about three miles, before it could be launched. A number of other iron boats were built at Oakbank, including two for England, one for Ireland, and one for Russia. The one last referred to was a passage-boat seventy feet in length, for canal traffic. It was sent out to Russia in three pieces, and it is understood to have been the first iron boat ever used in that country.

Along with his father and his two brothers, Walter and Hugh, the deceased, in the year 1840, started the Mossend Ironworks, near Holytown, about eight miles from Glasgow. These works were commenced exclusively for the manufacture of wrought iron, as the works started three years earlier at Summerlee, Coatbridge, by his eldest brother and partners, were intended only for the making of pig iron. Mr. Neilson began his iron manufacturing operations at the Mossend Works on a somewhat limited scale; but the establishment, which he started forty-two years ago, became in course of time the largest works of the kind north of the Tweed. As the growth of iron shipbuilding proceeded, the manufacturing powers of the Mossend Works had every now and then to be extended in order to meet the increasing demands for their specialties, in the shape of ship and boiler plates, large sections of deck beams, angle bars, and general merchant bars. Mr. Neilson was ever ready to adopt the most advanced notions as to rolling machinery and other plant, with the view of maintaining the reputation which had been secured by the finished iron branded "Mossend."

Mr. Neilson was one of the first iron manufacturers in Scotland to adopt reversing gearing for rolling-mills, and to introduce for reheating purposes the Siemens regenerative furnace. Some time ago, he added the manufacture of steel on the Siemens system to the capabilities of the Mossend Works.* This department has now been in operation for more than a year and a half, with very successful results. Mr. Neilson became a member of the Iron and Steel Institute in 1871, and took an active part in the arrangements for the Glasgow meeting in the following year. He was also a member of the Institution of Engineers and Shipbuilders in Scotland, and of several kindred Societies.

Mr. WILLIAM BARNINGHAM, of Springfield, Darlington, and Pendleton, near Manchester, died at Pendleton on the 3d November last, after a long and severe illness. The deceased was born at Arkingarthdale, near Richmond, Yorkshire, in 1826. He was the youngest of eleven sons and two daughters. His parents were poor, but their family was ancient. They were the original proprietors of the village of Barningham-on-the-Greta, which now forms part of the Millbank estate.

Young Barningham's first employment was to carry the letters from the post-office at Reeth, and deliver them at the village where he was born. In 1839 he travelled to Shildon (then the chief centre of the repairing works of the Stockton and Darlington Railway) in search of work, but not finding it there, he went to Middlesbrough, where he got employment as a blacksmith with his brother John. Here he soon began to develop mechanical genius, showing much ingenuity in the construction of small engines. His brother and he also acquired celebrity as makers of switches and crossings for railways. In September 1843, Mr. Barningham and his brother went to France, expecting to find employment on the Paris and Rouen Railway, then being constructed by Messrs. Brassey, Mackenzie, & Co., who employed them on the permanent way of the new line. William Barningham, while so employed, laid before Mr. John Jones, the manager for Messrs. Brassey, Mackenzie, & Co., a plan he had conceived of making switches and crossings out of rails and railway chairs in separate sections, instead of making them all in one piece. He was allowed to carry his idea into practice, with the result that he realised about £300 in little over six months. Returning to England, he and three of his brothers commenced a foundry at Manchester. This was not a success, and in eighteen months Mr. Barningham had lost all he had gained in France. He now (1845) visited the Cleveland district, and there met Mr. John Harris, of the Stockton and Darlington and the Wakefield and Goole railways. Mr. Harris suggested that he should commence works in Middlesbrough for the manufacture of railway switches and crossings. With a capital of £1000, advanced on loan, these works were started, and proved a financial success. In travelling about the country seeking orders for his work, Mr. Barningham observed large quantities of worn-out iron rails lying about the works of the Lancashire and Yorkshire Railway Company. These rails were returned to different places in Staffordshire, Wales, and Scotland for re-manufacture. Mr. Barningham considered that this re-manufacture might as well be done on the spot, and got from Admiral Lows, general manager of the Company, a contract for the re-manufacture of 4000 tons of rails and 2000 tons of railway chairs. This was the origin of the Pendleton Ironworks, the geographical position of which, however, prevented them from being available for the manufacture of rails on a large scale. Mr. Barningham, for this reason, determined to establish new works in Cleveland. The works at Albert Hill, Darlington, were thus originated, and it is no secret that they were carried on for many years with almost unvarying success, until in 1873 they were transferred to a limited liability company. Mr. Barningham subsequently undertook considerable speculations in lead and copper, and at his death had amassed a large fortune.

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* *Journal of the Iron and Steel Institute*, No. I., 1881, p. 224.

Mr. **Alfred Kitching**, who died at Darlington on the 13th February last, was born in 1808, so that he had attained his seventy-fourth year. His elder brother, Mr. John Kitching, was one of the earliest subscribers to the Stockton and Darlington Railway. Another brother, Mr. William Kitching, was a director of that line up to the time of his death in 1850. For some years previous to that time the deceased gentleman had also had a seat on the Board of that railway, which he retained until its amalgamation with the North-Eastern Company. He was one of the oldest living directors of the North-Eastern, and was for many years a representative of the Company on the Hartlepool Port and Harbour Commission. He had also a seat on the Cockermouth, Keswick, and Penrith Board, and possessed large industrial interests in Darlington and its neighbourhood.

In 1832, Mr. Kitching began an iron foundry at Hopetown, Darlington, where many of the earliest locomotives and waggons were built for the Stockton and Darlington Railway—the first passenger line in the kingdom. A large amount of general foundry work was also done there. In 1862 he removed his business to the present Whessoe Foundry at Darlington, now carried on under the style of Messrs. Charles Ianson, Son, & Co. In 1866 he promoted the Rise Carr Rolling Mills. He was first a promoter and subsequently a director of the Darlington Water Company, of the Stockton and Middlesbrough Water Company, and of the Croft and Hurworth Gas and Water Company. He had, moreover, a place on the directorate of the Weardale and Shildon Water Company, the South Bank and Normandy Gas Company, and the Saltburn Improvement Company.

Mr. Kitching was for many years previous to the incorporation of Darlington, in 1867, a member of the old Board of Health; and on the incorporation of that town coming into effect, he was appointed an Alderman, which he remained up to his death. He was chosen Mayor of Darlington in 1870, and had long been a borough magistrate.

Mr. Kitching was a member of the Society of Friends, and married in 1852 Miss Cudworth of Darlington, who survives him. He leaves three sons, John, Alfred Edward, and Henry. He became a member of the Iron and Steel Institute in 1872, but he never took part in any of its proceedings.

Mr. **Henry Currer Briggs** was born at Overton, near Wakefield, Yorkshire, on the 2d March 1829. He was almost entirely under private tuition until the age of thirteen, when he went to Dr. Heldenmire's school at Worsop, then newly established on the Pestalozzian system. He remained there for some years, and finally went to Edinburgh University, where he specially distinguished himself in chemistry, making many experiments in the laboratory of the late Professor Wilson, in concert with that distinguished chemist.

His university course at an end, Mr. Briggs returned to his native place, and assisted his father in the management of the collieries at Flockton, near Wakefield, where he made himself master of all the details of underground working. He did not, however, work there long, but, from the time he came of age, devoted his energies chiefly to the management of Whitwood Colliery, near Normanton, then just opened out by his father. After a period of fifteen or sixteen years of earnest and unremitting work, successful for the most part, but frequently disturbed by strikes and disputes with the workmen, he was deeply impressed by the desirability of introducing a system of co-operation between masters and workpeople in place of the antagonism that was wont to exist. With this end in view he worked out a scheme which he hoped would do away with all cause of strikes by making the interests of the employer and employed identical.

In 1865 the Whitwood Collieries were transferred to a limited liability company, the capital being taken at the amount standing in the books of the concern. The workpeople were specially encouraged to take shares, a preference being given to their applications, and arrangements being made for payment by gradual instalments. In addition to the attempt to interest the workpeople in the success of the concern by making them shareholders, a still more important feature of the scheme was a payment to all workpeople and officials of the Company of a bonus on their earnings at the end of each year, the sum to be paid being dependent on the profits of the Company. During the ten years in which the system was in operation, including the inflation of 1873, over £40,000 was distributed to the workmen in this way. For some years the new system worked most successfully, and might have continued to do so, but for the excessively high wages of the two years culminating in 1873, which made the men indifferent to what seemed to them then a comparatively small benefit deferred to the end of the year. Other causes, too intricate to be detailed here, combined to break up the bonus system, and make the shareholders generally unwilling to continue the benefit to those who seemed so indifferent about it. Many of the more thoughtful of the workmen have since deeply regretted the course then pursued by some of their number. To Mr. Briggs, the overthrow of his scheme was a source of great sorrow. He was not at that time managing director of the Company, although he still retained the office of chairman, having become a partner in some jute works in Dundee, where he resided for about four years.

In the year 1870 Mr. Briggs returned to England, and established "The North of England Iron and Coal Company (Limited)," now "The Carlton Iron Company (Limited)," in the Cleveland district, having long had a great desire to try the same principle of industrial partnership in the iron trade which had up to that time been so successful in the coal trade. Unfortunately, however, the great and long-continued depression in the Cleveland district, which commenced before the new Company had had time to become firmly established, prevented the system from having a fair trial; and in 1876, when family circumstances obliged Mr. Briggs to resume his former position at the Whitwood Collieries, the Carlton Iron Company passed into other management, although he retained the chairmanship to the time of his death.

This is not the place or time to discuss the subject of the experiments made at Whitwood and Carlton by Mr. Briggs. It may, however, be remarked that they were watched with deep interest by employers of labour, political economists, and representatives of labour throughout the country; that many looked to industrial partnerships as the long-sought-for panacea for industrial dissensions; and that the Whitwood experiment was the pioneer of many others of a more or less modified character, tending to the same end.

At the instance of Mr. Briggs, some of Danks' rotary puddling machines were in 1874 erected at the ironworks at Carlton, near Stockton, but with unsatisfactory results. The results obtained at the Carlton Works with the Danks furnace were described by Mr. Briggs at meetings of the Institute,* this being, indeed, the only subject on which he ever addressed the Institute, of which, however, he had been a member since 1872.

That Mr. Briggs' efforts to ameliorate the condition of his workpeople were fully appreciated by them is shown by the following inscription on a monument which they have erected to his memory in the churchyard at Whitworth:—

"This monument, erected by the workmen and others connected with the Whitwood Collieries, commemorates a master who, by his exemplary Christian character, faithfulness, and diligence in his vocation, and lifelong endeavours to improve the condition of those who worked under him, won for himself their true affection and esteem, and whose sudden death was deeply lamented and deplored."

To this eloquent and exceptional tribute little need be added. A friend who knew him well has, however, borne testimony that "his thorough uprightness and straightforwardness were felt and appreciated by all who came in contact with him, and he was especially remarkable for faithfulness in everything that he undertook, however great the suffering or loss to himself." He died suddenly at Christiania, Norway, on the 21st October 1881.

Mr. JOHN GEORGE CHAPMAN, of Tower Hill, Middleton-St.-George, Darlington, died on the 19th November, at the age of fifty-one years.

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* *Journal*, 1874, p. 40, and 1876, p. 397.

He was born at Crook, where, along with Mr. Morson, he afterwards worked some collieries. He subsequently acquired the largest stake in the Tees Bridge Furnaces at Stockton-on-Tees and the adjoining rolling and plate mills at Bowesfield. Upon the Ferryhill Colliery being laid in after the stagnation which began about 1874, Mr. Chapman and his partners acquired the freehold of the colliery and farm. They also purchased a moiety of Cold Knott and Hargill Collieries, in Durham, where coke ovens and brickworks were erected, and about the same time, or a little later, they became owners of Howden Colliery, with the coke ovens and brickworks attached thereto. From first to last, therefore, the deceased gentleman had a large stake in the coal trade of Durham, and did a good deal towards developing those mineral resources upon which the Cleveland iron trade depends for its prosperity.

Mr. Chapman was the managing director of the Tees Bridge Ironworks at Stockton-on-Tees, where blast furnaces have been carried on for a number of years; and he was also a director of the adjoining Bowesfield Ironworks, where finished iron of various descriptions is produced. He was a director of various other concerns in his own district, and took an active part in public affairs, political and otherwise.

Elected a member of the Iron and Steel Institute in 1874, Mr. Chapman was a regular attender at its meetings, both in London and elsewhere. He was also a member of the North of England Institute of Mining Engineers and of the Cleveland Institution of Engineers. In private as well as in commercial and public life, the deceased was one of the most genial and agreeable of men.

NOTES

ON THE PROGRESS OF

THE IRON AND STEEL INDUSTRIES OF THE UNITED KINGDOM IN 1882.

BY THE GENERAL SECRETARY.

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A.—METALLURGICAL TECHNOLOGY.

I.—*ORES AND FUEL.*

The Iron Ores and Mines of Cleveland.—Mr. Thos. Allison of Guisbrough, has communicated * some particulars respecting the ironstone deposits of Cleveland, which may be said to bring up to date the information previously available on that subject.† There are twenty-three mines working in the district, yielding about seven million tons of ironstone per annum, while eight others, equal to a further production of two million tons, were idle in April of this year. Sixteen mines are worked by drift, four by drift and pit, and fifteen by pit only. The thickness of the bed of ironstone varies from a minimum depth of 5 ft. 9 in. at Roseberry, to about 16 ft. at the Eston and Challoner mines of Bolckow, Vaughan, & Company. Taking Eston as the central point of the main bed of ironstone, the deposit decreases in thickness towards the west, east, and all round the southern semicircle, but mostly to the south-west, while the thickest part of the Eston bed is over three times that of the same seam in Roseberry. Three and a half miles distant, it is found that the deepest part of the Eston bed is more than 700 feet below that in Roseberry. This is mainly due to a large fault, which runs nearly parallel with the southern part of the Eston and Upleatham Hills. It is presumed by the author that the latter, with that of Skelton, have been off-breaks from the main mass of the oolitic and lias formations, the valleys between having become lagoons, which are now silted up with alluvial deposit to the depth of 60 to 80 feet.

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* *Proceedings of the Cleveland Institution of Engineers*, Session 1881–82, p. 160.

† *Journal*, No. II., 1871, p. 172; 1874, p. 329; 1878, p. 245; 1880, p. 248.

The New Lime Process of Getting Coal.—Since the application of the adoption of lime cartridges in place of gunpowder for the getting of coal was first formally announced * through the Institute, the new process has had a trial in most of the principal coal mining districts of England, as well as in Germany, Austria, and Belgium. In Yorkshire, it has been tried in 13 collieries; in Lancashire, experiments have been made in 16 collieries; the coalowners of Durham have tried it in 9 different pits; and it has also had a trial in the Cunnock Chase, Warwickshire, Staffordshire, and South Wales coalfields. The general results may fairly be described as satisfactory—so much so, indeed, that the patentees of the process have been requested to furnish the necessary cartridges for an output of nearly 12,000,000 tons of coal per annum. As it would be extremely inconvenient to erect the necessary presses for the manufacture of the lime cartridges at each individual colliery where the process was used, it has been arranged to erect factories in different districts for that purpose, and the first factory will be commenced very shortly at Whitburn, near Sunderland—where there are large deposits of nearly pure carbonate of lime—for the supply of the Durham district. In a general way, it may be stated that the owners of the collieries to the working of which the new process has been found applicable, have satisfied themselves that it is calculated to yield more economical results than gunpowder, having regard to the much greater percentage of large coal got by its use. It has not, however, been found equally adapted to all coal seams, and the patentees have found it necessary to seek for certain modifications of the process with a view to its adaptation alike for soft and hard coal. Neither has it yet been applied to the getting of any other mineral, although the results of experiments made at the Channel Tunnel and elsewhere encourage the belief that it may ultimately be found suitable for the getting of ironstone, &c.

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* *Journal of the Iron and Steel Institute*, No. I., 1882.

Recovery of Volatile Products in Manufacturing Coke.—*Engineering* of December 8th 1882, announces that Mr. John Jameson, of the firm of Jameson & Schaeffer, consulting engineers, Newcastle, has invented a new method of distillation, which is attracting some attention in the north of England. The process consists in withdrawing the volatile products and cooling them in a range of pipes, so as to allow the condensible hydro-carbons and ammonia water to be deposited, while the incondensable gas is either used as a bye-product, or is passed into the lower part of an entirely ignited oven, where the carbon of its hydro-carbon is deposited in the pores of the coke. In the ordinary process of coke-burning, the ignition of the coal begins at the top of the oven and proceeds downwards. Under the action of the heat the coal softens and agglomeration of the particles takes place, accompanied by the evolution of gases and vapours, which find their way towards the surface, where the former are, for the most part, burned, and the latter decomposed and lost. As the process proceeds, the stratum of agglomerated particles thickens, and as the heat increases the products separate, the more volatile forcing their way to the surface, and the less volatile becoming set in the charge and coked. Under the new process these conditions do not obtain. The vapours formed at the lowest possible heat pass at once into a colder stratum of coal, the raw coal being gradually warmed and its most volatile products caught away, while the least volatile may be left to enrich the coke. The yield of oil and ammonia varies with the quality of the coal, the quantity obtained from Sherburn coal being 6·8 gallons of oil per ton of coal, and a quantity of ammonia equal to 4 lb. to 6 lb. of ammonia sulphate. An analysis of the oil showed solid paraffin to the extent of 17 to 23 per cent. It is stated that the cost of application of the invention to a row of coke ovens need not exceed £20 per oven. Some important results have also been obtained with the Carvès system of coking at the collieries of Messrs. Pease, near Darlington.

The Hematite Deposits of Furness.—Mr. J. D. Kendall (*Transactions of the North of England Institute of Mining Engineers*, June 1882), divides these deposits into three classes, viz.:—1, the vein-like; 2, the dish-like; and 3, the irregular-shaped. Bed-like deposits are not a characteristic of the district, owing to the rocks being everywhere of the same character. In the vein-like deposits, which include some of the most important in the district, there is a general narrowing downwards, notwithstanding the great variations in their width. The one at Lindal Moor is perhaps the finest of this class, being worked for 1000 yards in a direction N. 25° W. Its breadth is very variable, from a few inches to 30 yards, due to the irregularity of the hanging wall, the foot wall being regular. The bottom seems to have been reached at the north end, at a depth of between 60 and 70 fathoms; it lies alongside a fault. Similar deposits, generally under similar conditions, occur at Stank and at Yarlside. The dish-like deposits are the most numerous, and they occur just below the drift. The Park deposit, which is the largest of this or any other class, is very irregular in form. It is about 360 yards long E. and W., and 260 yards N. and S., and is overlain by a drift of an average thickness of 10 fathoms. The ore extends to at least 83 fathoms from the surface downward. Although the basin contains large quantities of sand and clay, yet it holds an enormous deposit of hematite, all others being much less. Of the irregular-shaped deposits, the one at Askam is the only good sample; at one part it is immediately below the surface, and at another it is entirely surrounded with limestone. The author here dissents from Mr. Greenwell's opinion that it is a bed-like deposit, and that there is any unconformity in the limestone above and below the ore. In their nature the deposits differ from those near Whitehaven, inasmuch as they are not interbedded with shale to anything like the same extent; they are, however, frequently interrupted by large masses of stone connected in some way with the main limestone. Some of the dish-like deposits have masses of red and white sand in them; in these and in some of the vein-like deposits of red, yellow, and white, clays are met with, which, when hard, are called "hunger." This generally surrounds the ore, and separates it either from the limestone or the sand and other foreign substances. This clay, which sometimes contains vegetable matter, even permeates the fissures and fills the irregularities of the limestone casing. The hematite in the northern part of Lindal Moor deposit and at other places is hard, compact purple ore, with numerous "loughs" lined with kidney-like concretions and spar, containing from 78 to 94 per cent. of ferric oxide, 55 to 66 per cent. of metallic iron, with a specific gravity of from 4·3 to 4·8. Although it looks compact, yet the microscope discloses a number of minute cavities containing silica; the larger visible cavities called "loughs" also contain silica in the form of quartz spar, and, as in Whitehaven, the kidney ore invariably is to be found round these loughs. In the south of the Lindal Moor deposit and elsewhere the ore consists of hardish pieces of dull, reddish purple, and softer of a bright red, in the interstices of which is found a soft, greasy substance called "smit;" it contains from 77 to 86 per cent. of ferric oxide, 54 to 60 per cent. of metallic iron, with a specific gravity of from 4·0 to 4·4. This ore contains microscopic cavities, sometimes filled with quartz and sometimes empty. At Gilbrow, a number of fossils are found in the ore, belonging to the carboniferous limestone, wholly and partially converted into hematite. The most common kind of ore is similar in its character to the above, but is found in lumps about the size of a man's hand, containing no "loughs," and set in a softish dark red brown or nearly black matrix, consisting of "smit" clay and manganese; it contains from 60 to 84 per cent. of ferric oxide, from 42 to 49 per cent. of metallic iron, with a specific gravity of from 3·6 to 4·3; its distinguishing feature being the large proportion of manganese it contains. Generally, the other minerals associated with the ore are baryte, calcite, pyrite, quartz, and manganite. The latter portion of the paper treats of the age of the deposits, which the author, agreeing with Professor Philips, considers, as far as West Cumberland is concerned, to belong to the early Permian age.

New Coal-Cutting Machine.—Mr. C. Burnett, of Spennymoor, has brought out a new form of coal-cutting machine, which is adapted for working on the system known as "bord and wall," and is said to be capable of turning out 50 tons in a 3 ft. 6 in. seam in twelve hours. The apparatus consists of a feeding screen, to which is attached a cylindrical cutter-head provided with cutters $\frac{3}{4}$ in. wide, for producing cylindrical blocks of coal of say 2 ft. 6 in. long, and 1 ft. 8 in. diameter. There is also a cutting head for producing small coal for coking purposes. The machine is specially designed to work in a 2 ft. seam, and is shown with a disintegrating cutter-head 2 ft. in diameter, which will cut away the whole height of the seam, and reduce the coal to "small," ready for coking. This cutter-head consists of a central boss having four radial arms, into which are fixed several small cutters helically arranged, each cutter being secured in position by a nut at the back. The boss, which is 3 in. diameter, projects about 6 in., and forms a drill, which serves as a guide in the operation of cutting the coal. The cylindrical cutter-head for producing blocks is of wrought iron, bored and turned and finished, $\frac{5}{16}$ in. thick. The cutters, of which there may be three or more, are $\frac{3}{4}$ in. wide, and are secured to position in slots in the periphery. The cutter-head, moving axially with the feeding screw, cuts a $\frac{3}{4}$ in. annular groove in the coal. It may be used for "kiding" only, or it may be also used to take down the top coal in blocks. The top coal may, however, be wedged down if preferred. The cutters are operated by an engine having a pair of 7 in. single acting cylinders with 6 in. stroke, the cylinder of which forms the standard for the machine; and the crank shaft is connected to the feeding screw by suitable gearing. The apparatus is provided with a jack screw for securing it in position. It is designed to work with compressed air through a 1¼ in. flexible hose.

Boring for Ironstone with the Diamond Drill.—Mr. Henry Davey, of Leeds, after noticing[*] that the diamond drill is specially useful for putting down trial bore-holes, as the boring tool cuts an annular groove, and brings up solid cores of the strata passed through, gives the following statements of work done in making trial borings for ironstone with this drill:—

Borings for Ironstone with the Diamond Drill.

Number of Boring.	Length of Time occupied.				Total depth of Hole bored.	Average depth bored per Hour.
	Total Time.	Lifting and Lowering Rods.	Other Accessory Work.	Actual Boring.		
No.	Hours.	Hours.	Hours.	Hours.	ft.	ft.
1	59¾	11¾	32½	15½	79	5·08
2	152	83½	43	25½	207	8·10
3	48	11	20½	16½	72	4·36
4	44	10½	17½	16	69	4·30

The size of each hole was 1·89 in. diameter throughout from top to bottom; and the average cost, including all contingencies, was 7s. 6d. per foot of depth.

The author found it very difficult to ascertain the cost of boring in England. He has, however, obtained the data given in the appended table as to the cost of trial bore-holes for ironstone in the Barrow district, with steam winch and free-falling tool, and passing through strata consisting of sand, shale, sandstone, and limestone.

Cost of Trial Bore-holes for Iron Ore.

Depth of Hole.	Diameter of Hole.	Cost per Yard.	Cost of Labour alone.	Time occupied.
Yards.	inches.	*s.* *d.*	£ *s.*	Weeks.
126	6 to 2	7 10¼	49 10	15
124	6 ,, 2	9 7	59 8	18
50	6 ,, 2	9 10¾	24 15	7½
63	6 ,, 2	9 5	29 14	9
76½	6 ,, 2	6 0½	23 2	7
88	6 ,, 2	8 3	36 6	11
48	6 ,, 2	11 0	26 8	8

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[*] Paper on "Mining Machinery" read before the Institution of Mechanical Engineers, August 1882.

The diamond drill has also been proposed as a means for sinking shafts; that is, to perforate the entire area of the shaft with holes bored to the full depth, then nearly fill up these holes with sand, insert dynamite above the sand, fire it, and remove the *débris;* then to repeat the operation by clearing out the sand to a certain depth, and inserting a fresh charge of explosive. The economy of this system was tested at the Van der Heydt Colliery near Saarbrücken; but it was found that sinking by hand in the usual way was much less costly.

II.—*BLAST FURNACE PRACTICE.*

The Position of the Tuyeres in Blast Furnaces.—Mr. Charles Cochrane, in a paper on this subject read before the Institution of Mechanical Engineers in August last, stated that two important elements in the successful working of a blast furnace have been overlooked or altogether ignored—namely, the size of the hearth, and the overhang of the tuyeres, or, as it may be put by preference, the distance of the tuyeres apart across the hearth. The experience gained by the author during the past eight years, and his special observations during the last two of these, point to the fact that, in the employment of high temperatures of blast, the distance of the tuyeres apart from nose to nose is of great consequence; and that, *cœteris paribus*, if they approach too close together, the effective capacity of the furnace is materially reduced. This reduction may easily go so far as to destroy the economy which should have resulted either from extra cubic capacity of the furnace, or from extra temperature of blast employed. In this way, a furnace of 20,454 cubic feet actual capacity has been lowered to only 12,000 cubic feet effective capacity, and the consumption of coke increased from about 21 cwt. to about 25 cwt. per ton of iron made; in other words, a furnace of only 12,000 cubic feet actual capacity, working efficiently, would have done as good duty as the furnace of 20,454 cubic feet capacity actually did. Again, in a furnace of 35,013 cubic feet actual capacity, the effective capacity has been reduced to 26,000 cubic feet, and the coke consumed per ton of iron has been raised from 19¾ cwt. to 20½ cwt., besides other unsatisfactory results consisting of a somewhat diminished make of iron, and the occasional production of an over-grey quality.

The author's observations have extended to four different blast furnaces. No. 1 furnace is of 33,400 cubic feet capacity; No. 2 furnace is of 35,013 cubic feet capacity; No. 3 furnace is of 20,454 cubic feet capacity; No. 4 furnace is of 20,454 cubic feet capacity.

No. 1 furnace was constructed with a hearth of 10 feet diameter, and an overhang of 16 in. of tuyeres, making the distance apart of opposite tuyeres 7 ft. 4 in. across the hearth from nose to nose. It was blown in on 18th March 1874. No. 2 furnace was constructed with a hearth of 8 feet diameter, and an overhang of 12 in. of tuyeres; making the distance apart from nose to nose 6 ft. It was blown in on 10th May 1876. In June 1880, the tuyeres at this furnace were each drawn back 8 in., making the distance apart of the tuyeres, from nose to nose, 7 ft. 4 in. No. 3 furnace was constructed with a hearth of 8 ft. diameter, the distance from nose to nose of tuyeres being 6 ft., and was blown in on 27th November 1876. No. 4 furnace was constructed exactly as No. 3, and was blown in on 8th January 1880. At the end of January 1882, the tuyeres were drawn back to a distance of 7 ft. apart, with excellent results. Commencing with No. 4 furnace—the tuyeres of which, till the end of January 1882, had been only 6 ft. apart, and, during the months of February and March 1882, were separated to a distance of 7 ft. apart—the following results were obtained:—The make, which had been limited to an average of 483 tons per week over the preceding months of November, December, and January, rose in March to 599 tons per week; whilst the gross consumption of coke was only increased by 27 tons, or from 603 up to 630 tons per week. The tuyere area was unaltered, being 141 sq. in. total. The temperature of escaping gases at the tunnel head in March was 100 deg. Fahr. less than before the withdrawal of the tuyeres, viz., 617 deg., whereas previously it had been 717 deg.; and the temperature of blast was increased by 109 deg., being 1321 deg. in January and 1430 deg. in March. The result of the tuyeres protruding too far into the furnace is, that a larger volume of heated and expanded gases per sq. ft. of transverse sectional area must necessarily be developed up the centre of the hearth than at its circumference. In No. 4 furnace, after the tuyeres had been drawn back so as to be 7 ft. apart, pressures were observed within the futnace as follow: At centre of hearth, 2⅞ lb. per sq. in.; at 1 ft. back from centre, 3 lb. per sq. in.; at 2 ft. back from centre, 3 lb. per sq. in; at 3 ft. back from centre, 3⅛ lb. per sq. in; at 4 ft. back from centre, *i.e.*, inside the nozzle of blast pipe, 3⅛ lb. per sq. in. The pressure of blast at the plug hole before and after the experiments was 3⅜ lb. per sq. in. There was thus a steady reduction of pressure from 3⅛ lb. to 2⅞ lb., or a total reduction of ¼ lb. from the circumference to the centre of the hearth. The day on which the work commenced of drawing back the tuyeres at No. 4 furnace of 20,454 cubic feet capacity from 6 ft. to 7 ft. apart from nose to nose, the slag turned grey, indicating a much higher temperature in the hearth; and it was necessary to cool down the heated blast by an admixture of cold air until the heavier burden of ironstone and limestone, which the furnace ultimately proved itself capable of carrying on a standard weight of fuel, had worked its way down to the hearth. The result of drawing back the tuyeres from 6 ft. to 7 ft. apart was, in fact, to prevent the centralisation of heat, and to bring about a uniform or more nearly uniform distribution of the ascending gases over the whole transverse sectional area of the furnace. Occasionally an accidental, and at the time inextricable, production of glazed iron took place at this furnace, before the tuyeres were drawn back. It is believed that this was due to an accidental increase of temperature in the hearth through concentration of heat, by which the iron and slag became overheated towards the central part of the hearth, whilst the bulk of the cast would present no exceptional appearance. Under the altered conditions of the tuyeres, when placed 7 ft. apart, none of the ore is subject to the influence of a greater volume of gas than is needed for its reduction, nor is any deprived of the volume needed to effect its reduction. Thus all the materials arrive at the hearth in a similar condition, equally ready to enter the region or zone of fusion, over the area of which the temperature is practically equable, and the volume of ascending gases per square foot of sectional area is practically the same. The main improvement in the output of iron, namely, the increase of the weekly make from 483 to 599 tons, was due to the fact that whereas the 483 tons of iron formerly required 603 tons of coke, or 24·98 cwt. of coke per ton of iron, there are now produced 91 tons extra iron, making 574 tons of iron, with the same weight of coke, and also 25 tons more iron with 27 tons additional coke, due to extra driving.

The author thought the results he had obtained brought out clearly the relative importance of the effects resulting from extra pressure of blast, from diminished temperature of blast, and from closer proximity of the tuyeres. An extra pressure of about 1 lb. in blast at the same temperature pushes the point of greatest intensity only an inch or two inwards. If the temperature of blast be lowered to 300 degs. or 400 degs., the point of greatest intensity is pushed in 3 in. or 4 in., so as to be 17 in. or 18 in. from the nose of the tuyere, instead of 14 in. But if the tuyeres themselves be pushed in, the direct effect is to reduce the diameter of the hearth by the same amount; so that when, as was actually the case at Nos. 2 and 4 furnaces under the conditions described in the paper, the tuyeres were only 6 ft. apart, the diameter of this circle of most intense action was diminished from 4 ft. 8 in. to 3 ft. 8 in.; and an intense upward central movement of the gases was the result, the ring of greatest heat being thus prejudicially forced inwards toward the centre of the hearth. Mr. Cochrane added, that the drawing back of the tuyeres to the extent of 6 in. was worth annually £3000 in the saving of fuel alone.

New Gun for Clearing Dust in Cowper's Stoves.—Mr. John Ellison of Ebbw Vale has devised a new system and arrangement of gun for clearing the dust out of the regenerator flues of Cowper's hot blast stoves. The gun is placed on the bottom of the stove—the direction of fire being vertical—and is fired by means of a Siemens' "Exploder," giving a "quantity" current. Figs. 1 and 2 of the annexed illustrations show the gun. It is made of Bessemer steel, bored out of the solid, and bolted to a four-wheeled carriage, to which a bracket is attached to hold the cable, and also a handle made of 1 in. gas pipe, which may be lengthened or shortened to suit the position of the gun in the stove. The fuse (fig. 4) consists of a paper tube containing two copper wires, joined at their extremities by a platinum bridge wire ·0015 in. diameter twisted round the ends and soldered. A small quantity of gunpowder is put in the end of the tube surrounding the bridge wire; the remainder of the tube is filled with paper. The fuse is connected to the exploder by a cable, about eight yards long, containing the two insulated leading wires. Fig. 3 illustrates the method of using the apparatus. When the stove has been two hours on blast, all the valves, except the air-valve, are closed, a cleaning door at the bottom of the stove is then opened; one end of the cable is attached to the exploder, and the other end—passing through a hole in the door in which a perforated wood plug is inserted to prevent damage to the cable—is secured to the bracket on the gun. The gun is then charged to the muzzle with ordinary blasting-powder, rammed very hard, the fuse inserted into the touch-hole, and the wires twisted round the leading wires of the cable (as shown in figs. 1 and 2). The gun is then placed in the stove in any desired position, the door closed, and the charge fired by turning the exploder handle; after which, the gun is withdrawn and bumped on the ground, muzzle downwards, to remove any dust, and is ready for another charge. The weight of the powder charge is 18 oz. Thirteen shots are usually fired in each stove at intervals of twenty-one days; the quantity of dust brought down varies from seventy to eighty-four cubic feet, which is removed at the cleaning doors. The thirteen shots are uniformly distributed over the bottom of the stove. This system of cleaning has now been in operation at the Ebbw Vale furnaces about eight months with satisfactory results, the stoves having worked continuously during that time, and as yet showing no signs of choking up. These stoves are

Fig 1

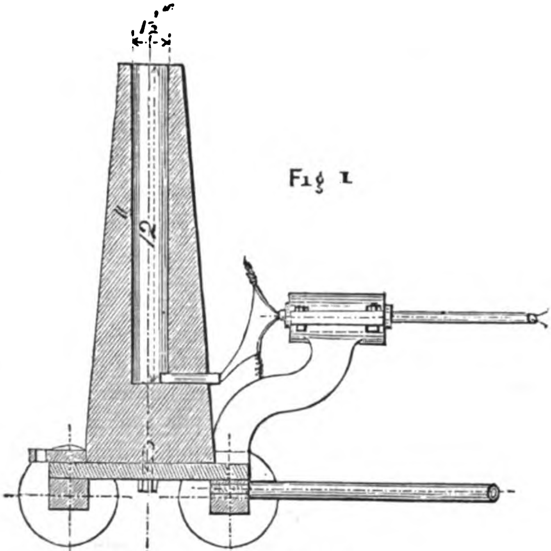


Fig 4

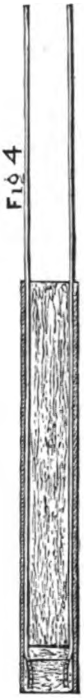


Fig 2

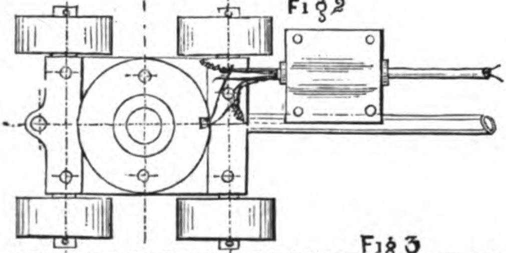
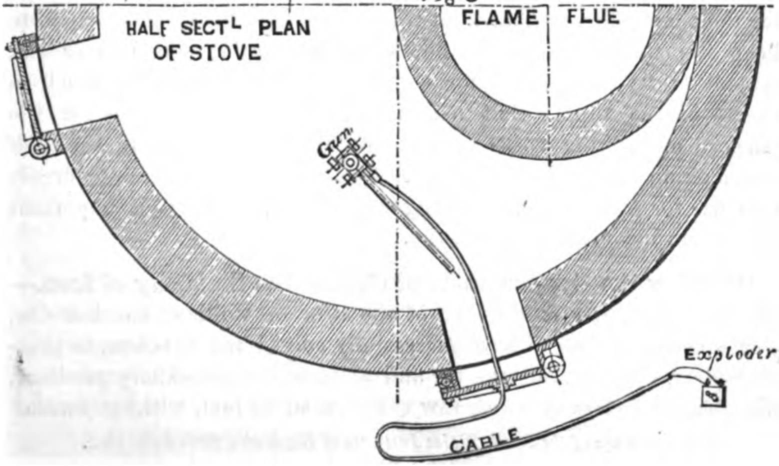


Fig 3



24 feet diameter by 48 feet high, to spring of dome, with regenerator flues 5¼ inches square. A stove can be cleaned in an hour and a half. The average temperature of blast at tuyeres is 1300° F. Mr. Ellison attributes the efficiency of the apparatus to the heavy powder charge it is possible to use, and to the fact that the direction of the line of fire is vertical. As an indication of the large volume of gas suddenly generated, it may be mentioned that a strong blast issues from the air-valve when a charge is fired.

Recent Results with Hot Blast Stoves.—At the Blaenavon Works, in South Wales, the adoption of Cowper's hot blast stoves, coupled with an increase in the pressure of blast from 3 lbs. to 3¾ lbs., has, according to Mr. E. P. Martin,* resulted in a reduction from 24 cwts. to 19 cwts. in the quantity of fuel consumed per ton of iron made. The average consumption for the five months ending July last in one of the Blaenavon furnaces fitted with Cowper's stoves was 18 cwts. 3 qrs. 26 lbs. Another furnace in South Wales has been working over a whole year with an average consumption of only 18½ cwts. of coke per ton of iron made. In the latter furnace, the economy of fuel has been attributed to some extent to the fact that it is unusually narrow for its height, its dimensions being 60 feet in height by 17 feet 6 inches in bosh.

Utilisation of Blast Furnace Slag.—At the Tees Ironworks, Middlesbrough, the manufacture of bricks and mortar from blast furnace slag is still continued, but the fall in the price of bricks from 40s. to about 25s. per 1000 has completely closed the London market for the time being, so that local trade alone is to be depended upon to keep the works going. Builders are now using slag mortar and cement pretty freely, and for slag wool the demand is so much in excess of the supply that negotiations are now going on for the purpose of erecting works to carry on the manufacture in the chief iron-making districts of England. The slag wool is coming largely into use for steamships, including men-of-war, where it is important to have an incombustible material.

Utilising the Bye-products of Coal in the Smelting of Iron.—Messrs. Alexander & M'Cosh, of the firm of William Baird & Co., Gartsherrie, are said to have successfully solved the problem, in practical form, of extracting the tar and ammonia, as subsidiary products, from blast furnaces in which raw coal is used as fuel, without increasing the cost of manufacture, or in the slightest degree disturbing the process of smelting. Some time ago works on a considerable scale was erected for this purpose at Gartsherrie Ironworks. The tar and ammonia are said to be largely recovered from blast furnace gases, which, after passing through the apparatus and parting with certain valuable products, are conveyed by piping to different parts of the works for the generation of steam and other purposes. So successful have these operations proved that the Gartsherrie firm are now erecting similar apparatus for all the furnaces at their various works in Lanarkshire and Ayrshire. The invention is expected to prove the most important innovation in Scotch iron smelting that has been adopted within recent years.

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* *Proceedings of the South Wales Institute of Engineers*, 20th July 1882.

The Economy of the Blast Furnace.—Mr. I. Lowthian Bell, F.R.S., in a paper on this subject,* which dealt exhaustively with the economical and practical working of the blast furnace, under different circumstances of construction, blast, and fuel, stated that the work of smelting iron was performed—including the blast, and reckoning every handling of matter as a factor in the calculation—for about 1½d. per ton, while the loss of metal was generally almost infinitesimally small, so that in his view, the more its economy was compared with any alternative mode hitherto proposed of extracting the metal from its ores, the less chance there was of the appearance of a successful rival to the blast furnace as now constructed. Having dealt with the functions of carbonic acid and carbonic oxide in the smelting process, the author gave estimates of heat absorption in furnaces under different conditions, and assigned to the use of hot blast, the following saving in coke (not pure carbon) per 20 units of iron :—

Replaced by heat in the blast . . .	5·25	cwt. per ton of pig iron.
Increased quantity of carbonic acid in gases .	1·00	,, ,, ,,
Reduced amount of heat carried off in escaping gases	4·75	,, ,, ,,
Diminished quantity of carbonic acid in limestone to expel and decompose, and less slag to melt	3·00	,, ,, ,,
	14·00	

No invariable rule, it was observed, can be laid down as to the size to which a furnace need be enlarged to avoid a loss of fuel from want of the necessary capacity, for there is the utmost diversity, as the author proved in the laboratory and at the furnace, in the readiness with which peroxide of iron obtained from different sources is reduced. In the large furnaces of Cleveland, for economical working, seventy-two hours is the ordinary period allowed for the ironstone to pass from the charging plates to the hearth; while in some Continental works Mr. Bell has visited, four hours suffice for the operation. A few months ago he saw a furnace in Savoy 24 ft. high with boshes of 6 ft., blown with the trombe, and therefore receiving its air surcharged with moisture. The calcined ore of the spathose variety only yielded 38 per cent.; 8 or 9 cwts. of limestone per ton of iron was being consumed, and yet cold blast grey forge iron was produced with 23½ cwts. of charcoal, not worth more, in a calorific point of view, than 20 or 21 cwts. of best Durham coke.

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* *Proceedings of the South Wales Institute of Engineers*, vol. xiii., p. 73.

Proceeding to consider the circumstances which impose a limit to the economical effects produced either by enlarging the furnace, or by heating the air, Mr. Bell stated that the capacity of the furnace requires to be sufficiently great to permit the gases to communicate all the sensible heat they are capable of imparting to the solids filling its interior. In a furnace having an altitude of 80 ft., when using about 21 cwts. of coke for smelting Cleveland iron, something like 6000 calories per 20 units of pig are carried off by the escaping gases. This in the state of oxidation of the carbon, and the temperature of the blast, may be taken as representing a little under 1½ cwt. of the coke employed. The question which naturally occurs to the mind is the possibility of this waste, or a portion of it, being avoided by a still further increase in the height of the furnace. Actual observation on furnaces 103 ft. high, satisfied Mr. Bell that no real advantage was realised by this addition of 23 ft.

It is true that the deoxidation of iron ore which takes place near the top, requires for its accomplishment a considerable quantity of heat, but the conversion of the carbonic oxide which effects the reduction evolves more heat than is absorbed by this process of deoxidation. Hence it happens that near the charging plates this balance of heat finds its way into the gases, and these not having time to impart their heat to the solids, it is carried away. Now, each addition to the height of the furnace beyond that point of equilibrium of temperature, established between the cooler solids and heated gases, merely means an elevation, in point of position, of the zone of reduction. In this way the distance between the reducing zone and the charging plates remains unaltered, and the gases, heated by the deoxidation of the ore, having no more material to pass through than before, remain unchanged in the temperature at which they finally leave the furnace.

Just as it was found that a furnace of 80 ft. in height with a capacity of something like 12,000 cubic ft., cooled the escaping gases as effectually as one containing 30,000 cubic ft., so Mr. Bell has ascertained that the lesser furnace permitted as perfect a saturation of the gases with oxygen gas as the larger one. Of course, in instituting this comparison, regard must be had to the quantity of iron produced in the two; because to obtain an identity of results, the product per 1000 cubic ft. of capacity, as well as the temperature of the blast, must also be identical. Practically, such a condition of things as that just described, viz., a like temperature and a like oxidation in the escaping gases, means that the consumption of coke is the same in both cases, other circumstances being also equal.

The largest quantity of carbon in the form of carbonic acid which the author has met with in the gases of a blast furnace was 6·52 units per 20 units of pig iron made. This, it will be perceived, is a very close approximation to what has been described as the theoretical maximum quantity of 6·58 attending the smelting of ordinary Cleveland iron.

In Mr. Bell's opinion, the copious precipitation and impregnation of ore by carbon, play a very important part in the economy of the blast furnace. It would be impossible to conceive more favourable conditions for the expulsion of the last portions of oxygen from the ore, or for the union of the iron with the needful carbon, than those presented by the intimate admixture of the two elements. It seems highly probable also that the precipitated carbon serves to some extent as a protection to the fabric of the furnace itself.

In order to judge of the character of the corrosive power of the cinder on the walls of the well, a firebrick was plunged into the slag runner of one of the Clarence furnaces, by which it was literally dissolved in the course of a very few minutes. Under such a condition of things Mr. Bell deems it incredible, that the crucible of a blast furnace, if unprotected, could withstand for any length of time the action of the quantity of intensely heated slag with which it is brought in contact, and he deems it probable that this protection is afforded by a species of igneous concrete formed of cinder and deposited carbon, the latter substance being also found in blowing out a furnace, in local deposits, as well as disseminated among the contents in large quantities.

The author's observation leads him to the conclusion that, with additional elevation, it is quite practicable and even useful to add something to the diameter of a furnace, because this can be done without interfering with the angle of the slope of the boshes. It would, on the other hand, be quite impracticable, and extremely detrimental to the proper action of the blast furnace, were it attempted to retain the former height and seek to gain the increased capacity by a mere alteration in its diameter. Indeed recent experience points to the fact, that even with very lofty furnaces errors have been committed in this direction, for there are examples in the north of England where, with the excessive height of 103 feet, boshes of 36 feet had to be abandoned.

To secure a capacity of 18,000 cubic feet, not an extraordinary one in our time, Mr. Bell finds a furnace, with a height of even 60 feet, would need a bosh of 32 feet with the greatest diameter only about 16 feet from the charging plates. Any practised eye, on laying down such lines on paper, would recognise at once the great facility which would be offered to the separation of the largest blocks from those of inferior size, which could not fail to produce the evil referred to as incompatible with good work.

It will, in Mr. Bell's opinion, be difficult to maintain, over a period of time, the blast at more than 850° C. to 900° C. (1562° to 1652° F.), by means of which we may hope to see iron from ore resembling that of Cleveland in quality, made at from 19½ to 20 cwts. of coke, requiring, as it often does, about 87,500 calories per 20 units of iron.

Such calculations as those which are used for illustrating the absorption of heat and consequent consumption of fuel, require to be materially modified according to the quality of ore and nature of the iron; thus, in smelting some varieties of ore, such as that from Bilbao, the flux required is so small that 75,600 calories suffice for producing 20 units of pig. At the same time, reduction is so easily accomplished that the ratio of carbon, as carbonic acid, to that in the form of carbonic oxide, was found to be as 1 to 2·09:—

The heat units per unit of coke consumed was therefore about .	3863
The heat units in blast of coke consumed was about . . .	540
	4403

The consumption of coke, upon one occasion, was as low as 17·60 cwts. although the air was only heated to 522° C. (971° F). It would, of course, be easy to add considerably to this blast temperature; but Mr. Bell is by no means certain that even the benefit of 1 to 1½ cwt. of coke would ensue from the change, for, by raising the heat of the upper region of the furnace, it is possible that part of the carbonic acid would be reduced by carbon to the condition of carbonic oxide, thus neutralising any gain from the additional calories contained in the blast.

III.—*THE MANUFACTURE OF STEEL.*

The New Tredegar Steel Works.—The Tredegar Company have recently laid down a new Bessemer steel plant at their works in South Wales. In its construction they have taken advantage of all the most modern improvements; and the plan on which it has been laid out differs in some important details from that of others in the district. The Bessemer shop is arranged for two pits, with a capacity of something like 3000 tons per week. One pit only is laid down at present. It is forty feet diameter, and furnished with three ingot cranes. The converters are placed on the opposite sides of the pit, and are turned with worm and wheel arrangement worked by hydraulic power. They are situated very conveniently to the blast furnaces, and the ladle containing the molten metal is raised by a hydraulic hoist placed in the centre of the two pits. A small stationary engine at the end of the platform brings the ladle opposite to each converter. The spiegel cupolas are on the level of the platform, convenient to the converters, and are filled by a hydraulic lift from the ground level. The blowing engines are of the direct acting vertical type, and work at an air pressure of 25 lbs. per square inch. There are two pairs of hydraulic engines which supply all the power necessary to work the cranes, &c. All the cranes and the converter tipping engines are worked from the pulpit.

The cogging engines are horizontal reversing, with cylinders 40 in. diameter by 5 ft. stroke, and are geared 2 to 1. The live rollers, worked by a small engine, are placed before and behind the rolls, which are too high, and the ingot is bloomed down to 7 in. square. A system of live rollers is laid in a direct line from the last groove of the cogging to the first groove of the roughing rolls. About a distance of forty feet from the cogging, on the line of these live rollers, bloom shears are placed in order to cut the blooms to any desired length. If the bloom is intended to be rolled off into rails, a switch is arranged so as to guide it straight to the roughing rolls of the finishing mill. The passing of the bar from the last groove of the roughing to the first groove of the finishing is done by a steam traverser. The finishing engines are horizontal reversing, with cylinders 48 in. diameter by 14 in. stroke. The rail when finished is carried by live rollers to the saw, and each length when sawn passes through a cantering machine, after which it is carried forward by a skid, worked by a rope, on to the cooling tank. The straightening machines, drilling machines, ending machines, and punches are all conveniently placed to facilitate the finishing of the rails.

The whole plant and machinery is designed so as to economise labour to the utmost possible extent. The rolling off of rails without any second heating has been going on since the commencement, and has altogether been very successful.

The Manufacture of Iron and Steel Sleepers.—Very little progress has been made, up to the present time, in the application of iron and steel to this part of the permanent way of the railways in the United Kingdom, but English engineers are specifying in many cases for steel and iron sleepers for foreign use. Mr. C. Wood states, that during the last twelve months he has had through his hands specifications for from 40,000 to 50,000 tons of metal sleepers, to be provided in conformity with the views he has laid down.* He has also furnished not only steel sleepers, but complete narrow gauge railways for different parts of the world, and has now on hand one for Africa, another for Fiji, and a third for the Cape. The tendency appears to be to adopt steel rather than wrought iron, which was the material invariably prescribed in the earliest specifications. This is due to the recognition of the fact which has been pointed out by Dr. Siemens,† namely, that in metal sleepers homogeneity is of great importance, because the metal is strained to a considerable extent where the fastening holds—an extent, indeed, which cannot be determined *a priori*—and in all such cases steel, being more tough and springy, yields before fracturing under compressive strains. On the North Western Railway, where Webb's system of permanent way ‡ is being extended, the results have been very satisfactory, and so with Wood's system of permanent way on the North Eastern. § At the present price of steel, the cost of sleepers of that material is scarcely any higher than that of timber; || and this fact, so long as it remains a fact, is likely to stimulate the new departure, which has proceeded so much more rapidly on the Continent than at home.

The Siemens Electric Furnace ¶ Applied to the Production of Iron and Steel.—This furnace consists of a crucible of any con-

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* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. lxvii., Part i.

† *Journal of the Iron and Steel Institute*, No. I., 1878, p. 102, and No. I., 1881, p. 151.

‡ Ibid., No. I., 1881, p. 124.

§ Ibid., No. II., 1879, p. 491.

|| Mr. Wood calculates, that the cost of creosoted wooden sleepers, per mile of railway, is nearly £100 per mile more than wrought iron sleepers on his system.

¶ Paper prepared by Dr. Siemens, F.R.S., and Professor A. K. Huntington, King's College, London, and read before Section B of the British Association at Southampton.

venient size, in the bottom of which is pierced a hole to receive the positive electrode; the negative electrode, which passes through a hole in the lid of the crucible, being suspended from one end of a beam, the other end of which is attached to a hollow cylinder of soft iron free to move vertically within a solenoid coil of wire. The force with which the cylinder is drawn into the coil can be counterpoised by a sliding weight on the beam. One end of the solenoid coil is connected with the positive, and the other with the negative pole. The coil having a high resistance, its attractive force on the cylinder is proportioned to the electro-motive force on the electrodes, *i.e.*, to the resistance of the arc. The length of the arc is therefore regulated automatically. This is a point of great importance, as, were it not so, the resistance of the arc would rapidly diminish as the temperature of the atmosphere within the crucible increased, and the result would be, that heat would be developed in the dynamo-machine. The extinction of the arc by sudden change in its resistance, or by the sinking of the material in the crucible, is thus also avoided. The crucible is surrounded with some infusible substance which is also a bad conductor of heat. Gas retort carbon or sand answers well for the purpose. The electrodes may be of such carbon as is used in electric lighting, or of any other convenient conducting substance. They may, if desired, be cooled by circulating water through or round them, or by exposing them as far as possible to the air. For example, in one experiment a ½-inch nickel positive pole was employed, the lower end being inserted into a solid rod of copper about 1 in. square by 6 in. long. With this pole, no other means of keeping it cool being adopted, 1 lb. of grain nickel was fused in a clay crucible and poured in eight minutes, starting with all cold. The electrode was but little attacked, and no leakage occurred.

There are two great advantages possessed by the electric furnace, viz., that the temperature attainable is practically only limited by the refractoriness of the materials of which the furnace is constructed, and that the heat is developed immediately in the material to be fused, instead of first having to pass through the containing vessel. The temperature to be obtained by the use of fuel is limited by dissociation. Deville has shown that carbonic acid undergoes dissociation at the ordinary atmospheric pressure at about 2600° C.—4700° F.

In the experiments made by the authors, five D 2 machines, driven by a Marshall's twelve horse power engine, were employed, one being used as an exciter. The current ranged between 250 and 300 Ampères.

The most refractory clay crucibles supplied by the Patent Plumbago Crucible Company were invariably cut through in a few minutes, and, except for experiments of short duration, were useless. Plumbago crucibles stood exceedingly well; obviously, however, they could not be employed for all purposes, owing to their tendency to cause carburisation of the metal experimented with. In some experiments the fusion of metal was effected in a bed of lime, sand, or electric light carbon-dust. The latter is a very bad conductor, and as in the case of lime and sand, allows the arc when once formed to maintain a passage through it to the metal beneath.

Wrought iron.—Six pounds of wrought iron were kept under the action of the arc for twenty minutes, and the metal then poured into a mould. It was found to be crystalline, and could not be forged. This is the result which has always been obtained when iron, nickel, or cobalt have been fused. Although the remedy, viz., the addition of a little manganese just before pouring, is well known, the cause remains still unexplained.

Steel.—As much as 20 lbs. of steel files have been melted in one charge, the time required being about one hour, starting with the furnace hot. With such large quantities the metal has invariably been full of blowholes.

White iron, fused in a clay crucible for thirty minutes, when fractured did not appear to have undergone any change. White iron and coke were introduced into the furnace; the resultant metal was slightly greyer than the original. When, however, retort carbon was substituted for the coke, a good grey iron, soft and easily workable, was readily obtained in fifteen minutes, starting with the crucible hot. On another occasion, starting all cold, at the end of thirty minutes the metal, although it had been well fused, had not been rendered greyer. The difference between these two results was possibly due to the temperature being somewhat higher in the one case than in the other. This is a point of considerable practical interest. Four pounds of white iron, fused with carbon-dust for three-quarters of an hour, yielded a very grey crystalline iron. In another experiment, in which eight ounces of grey iron, produced in the electric furnace from white iron, were re-melted in carbon-dust for ten minutes, a very grey metal was obtained, from which on slow cooling a large quantity of graphite separated.

Cast iron, fused and kept under the action of the arc for forty-five minutes in carbon-dust, was not materially changed as to greyness, and the general character of the metal as to the way in which it worked under the tool was not materially altered. The object of the experiment was to ascertain the maximum amount of carbon iron is capable of taking up under circumstances presumably the most favourable. The result is hardly that which would have been anticipated. Some of the same cast iron was fused for fifteen minutes under lime, which nearly covered it. The character of the fracture of the metal was but little altered by this treatment, when slight differences, due to the rate of cooling, are taken into account. A strong smell of phosphuretted hydrogen or of a phosphide was perceived—probably the latter. This was only observed in the experiment in which lime was used.

When *spiegeleisen* was fused in a plumbago or a clay crucible, graphite separated as the metal cooled.

Silicious pig iron, containing about 10 per cent. silicon, was fused by itself; it showed but little change, except that some graphite separated. A similar result was obtained when 5 lbs. of the silicious pig were fused for one hour in carbon-dust. On fracturing the ingot obtained, a large quantity of scales of graphite was found in a hollow which traversed nearly the whole length of the ingot at its centre. The fracture of the metal was still that so characteristic of highly silicious iron, and was practically the same as that of the original pig iron.

A series of experiments was made to determine the maximum amount of carbon pig iron is capable of taking up in the presence of a given quantity of silicon. Grey cast iron and pig iron, containing 10 per cent. of silicon, were fused together in carbon-dust, the ratio between them being varied so as to yield metal with from ½ per cent. to 9 per cent. of silicon.

The Basic Bessemer Process.—The recent development of this process has been very considerable, both in England and abroad. Nine converters are now being built in this country, and twenty-five on the continent, for carrying it on. These unitedly represent an output of 52,000 tons of steel per month, or 624,000 tons per annum, while thirty-eight converters are actually working the process at the present time. The total output of basic steel during the month of October was 47,717 tons, of which 9578 tons were produced at the Cleveland works of Bolckow, Vaughan, & Co., with four twelve-ton converters. The annexed statement, supplied by Mr. Gilchrist, shows the firms and the number of converters working the process in the month of October, with the actual quantity of steel produced by each:—

Country.	Name of Firm.	Address.	No. and Capacity of Converters.	Make for the Month of October 1882.
England	Messrs Bolckow, Vaughan, & Co.	Middlesbro'	Four converters, each of 12 tons.	9,578 tons.
France	Messrs. Schneider	Le Creuzot	Two ,, ,, 7 ,, (one Siemens' furnace of 10 ,,	Bessemer, 678 Siemens 562 } 1,240 ,,
Belgium	Les Acieres d'Angleur	Angleur	Two converters, each of 6 ,,	1,687 ,,
Germany	Aachen Hütten-Actien-Verein	Rothe Erde	Three ,, ,, 5 ,,	3,900 ,,
,,	Bochumer Verein	Bochumer	Three ,, ,, 4½ ,,	2,835 ,,
,,	Gutehoffnungshütte	Oberhausen	Two ,, ,, 6 ,,	1,335 ,,
,,	Hörder-Verein	Hörde	Three ,, ,, 10 ,,	4,100 ,,
,,	Peiner Walzwerke	Peine	Three ,, ,, 10 ,, (only 1 at work, started Sep. last.)	418 ,,
,,	Rheinische Stahlwerke	Ruhrort	Two converters, each of 6 tons.	3,500 ,,
,,	Union in Dortmund	Dortmund	Two ,, ,, 9 ,,	7,000 ,,
,,	MM. de Wendel	Hayange	Four ,, ,, 8 ,,	3,000 ,,
Austria	Prager Eisen-Gesellschaft	Prague	Three ,, ,, 5 ,,	1,854 ,,
,,	Teplitzer Walzwerke	Teplitz	Three ,, ,, 7 ,,	3,000 ,,
,,	Witkowitzer Bergbau	Witkowitz	Two (Holley) ,, 8 ,,	3,000 ,,
Russia	Société des Acieres de Varsovia	Varsovia		1,270 ,,
Total output for the month—England				9,578 } 47,717 tons.
,, ,, ,, ,, Continent				38,139 }
Representing an annual production of				572,604 ,,

Recent experience establishes the fact that it makes little or no difference in the product obtained whether the pig iron used contains 1½ or 3 per cent. of phosphorus. The more rapid wear of the linings, compared with the acid or ordinary Bessemer process, is now met, either by repairing the lining in fifteen to eighteen hours from blow to blow, or by the adoption of the Holley removable shell. When the lining is worn out, a new one can be introduced on the latter system in less than six hours. In recent experiments made with the basic process, some interesting results were obtained. The pig used had, before melting, the following composition:—

Constituents.	Strong Forge.	Grey Forge.
Manganese	1·12	1·13
Silicon	1·17	1·67
Sulphur	·08	·05
Phosphorus	2·97	2·72

The strong and grey-forge were mixed in equal proportions, and melted in an air furnace, when the resulting metal contained—

Manganese	0·75
Silicon	1·28
Sulphur	0·10
Phosphorus	2·94

The following table gives the chemical and mechanical results obtained from nine different blows:—

	A	B	C	D	E	F	G	H	I
Carbon	...	0·06	0·06	0·07	0·09	0·043	0·043	0·05	0·05
Manganese	...	0·51	0·34	0·31	0·47	0·29	0·31	0·26	0·49
Silicon	...	0·003	tr.	tr.	0·01	0·04	0·02	0·02	0·02
Sulphur	...	...	...	...	...	...	...	0·09	0·09
Phosphorus	0·042	0·04	0·05	0·05	0·08	0·03	0·10	0·08	0·08
Tensile strength, per ton, p. sq. in.	26·28	30·06	28·4	32·3	25·34	31·39	31·30	27·60	25·33
Elongation °/₀	27·8	19·2	23·9	20·8	22·9	24·2	25·0	20·8	28·6
Contraction of area °/₀	51·4	56·9	57·7	46·8	53·9	48·3	38·8	37·3	58·3

Basic Converter Linings.—Mr. Percy C. Gilchrist, in a paper on the basic process,* stated that there were three ways of making the converter linings required for the basic Bessemer process. Messrs. Bolckow, Vaughan, & Co. ground the lime and made it into roughly shaped bricks, and coal-fired them; Messrs. Schneider used the lime as it was obtained from the quarry and gas-fired it; and the third method was to place the lime in a cupola, much as pig iron was charged, and have the shrunk material drawn through, raking out every two hours, the coke used being from 13 to 16 cwt. per ton of shrunk material made. The lime, as then obtained, was ground up and mixed with hot tar, sufficient being used to make the material run solid under a red-hot rammer, or to make slurry if required. Basic converters were lined in four ways: (1) simply ramming round a wooden or iron core, and drying the lining with a coke fire after the core had been removed; (2) with the original basic bricks, using ground-up waste bricks mixed with tar for the joints; (3) with coked bricks (when these are used they are built dry, as the joints are true); and (4) with slurry (for a worn-out converter). The old lining, whilst still hot, had a cast iron core inserted in it, the nose section having been removed. When the core had been made hot with fire, slurry in lumps was thrown in between the core and the old lining. The heat caused the slurry to run liquid, and then dried it up hard. When this took place the core was removed, and the nose section put on. Each system had its partisans. The first required sixty hours to reline completely from blow to blow; in the second the converter was generally patched, and this was done in twenty-four hours from blow to blow; in the third the vessel was relined in fifteen hours from blow to blow; and in the fourth the relining was accomplished in eighteen hours.

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* Paper read before the South Staffordshire Mill and Forge Managers' Association, November 1882.]

Spectroscopic Analysis of Iron and Steel.—Messrs. Parry & Tucker are continuing their work on this interesting subject at the laboratory of the Ebbw Vale Iron and Steel Co., Monmouthshire. The following *resumé* of the results of their latest experiments has been prepared by the authors for the *Journal*:—

"The experiments commenced now many years ago by one of us (*vide Iron and Steel Institute Journal*, 1873), on the interesting subject of the absorption of almost any element by iron and steel at moderate temperatures, have been continued by the aid of the grant made us by the Royal Society, and have succeeded those experiments on the direct detection and estimation of bodies in iron and steel, the results of which were embodied in a paper presented to the Royal Society in the early part of this year.*

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* This paper was accompanied by a series of negatives of all the more common elements, and the different varieties of iron and steel.

"It is a natural inference from physical considerations that if the vapours of the metalloids or heavy metals be absorbed by iron and steel at high temperatures and pressures, as in many cases they undoubtedly are, the same bodies may probably be evolved when sufficiently heated in vacuo. This anticipated result we have found to occur, and in every instance where the vacuum has been good, and the heat fairly high, sublimates have collected on the cooler parts of the apparatus employed. The question then presents itself, what is the composition of the sublimates so obtained from ordinary steel? The smallness of the quantity obtainable renders the problem a difficult one. The sublimate is always very distinctly visible, but is excessively thin and altogether unweighable. The following arrangement for examination by the spectroscope was therefore adopted:—

"The spark from an 8-inch coil was passed through the metal under examination by means of the platinum wires shown in the cut (Fig. 1), the metal being heated simultaneously with the exhaustion. We have compared the spectra so obtained with those of the following elements—Copper, manganese, sulphur, phosphorus, arsenic, lead, and zinc. The following are our results:—

"Copper has been invariably detected in all the samples operated on. It is well represented by the simple green line 28·17.

"Manganese is also volatilised, and has been detected in Bessemer pig and steel as well as in spiegeleisen by this method.

"Sulphur, phosphorus, arsenic, and lead have not been detected by us.

"Zinc has been detected in spiegeleisen.

"Calcium, though so plainly visible with solution of iron and steel, has not been detected in these vacuo experiments.

"The ordinary heat applied to the metal was of course limited to the resisting power of the glass under exhaustion, and never exceeded that of a dull red. Four ounces of spiegeleisen, heated in a porcelain retort to the melting point of copper, gave the same spectrum as with the glass tube. A large surface of sublimate had formed in the tube, but the quantity was again too minute for collection and weighing.

"About 100 grains of steel were placed in a carbon cup working up to a carbon point. The whole was enclosed in a glass globe capable of exhaustion. On passing a powerful current from a dynamo machine* through the carbon, the steel was at once fused. A dense fume was then given off, and in a few minutes the globe burst with a loud explosion, indicating great pressure.

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* The authors think it proper to again acknowledge the services of Dr. Siemens in these experiments, that gentleman having prolonged the loan of a valuable dynamo.

"In order to, if possible, separate the volatile bodies from steel and from each other, we are now engaged in experiments with the following apparatus (fig. 2), which is perhaps sufficiently clear, it being simply a development of the former.

"We have observed that by varying the intensity of the spark either with or without an interposed Leyden jar or condenser, in combination with the spark micrometer, different spectra may be obtained. Thus when copper and calcium are present together, the copper line 28·17 cannot be seen. Without the jar the calcium group is also not visible, and copper only is now seen. The same phenomena occur with other elements. In thus manipulating the spark, we have been guided by experience, and have so arranged the jar and spark micrometer in order to always obtain, when possible, line spectra.

FIG. 1.

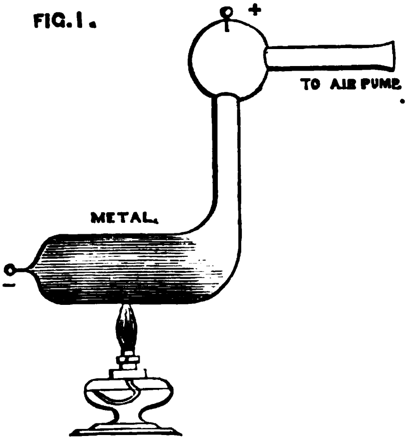
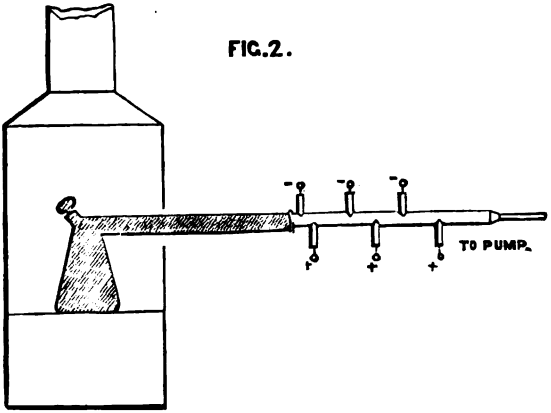


FIG. 2.



"This method of vacuum analysis, when carried out with the chlorides of the metals, is likely to lead to useful results. It affords a means of detecting minute quantities of elements far surpassing in delicacy the ordinary wet methods, and has not the disadvantage of ordinary spectroscopic work, where the presence of any large quantity of iron or other metal completely extinguishes the fainter spectra of other elements presumably present only in minute quantity.

"It will be noticed, from the arrangement of the apparatus, that we have adopted a kind of fractional distillation as the basis for experiment, and have therefore assumed that those bodies which are the most volatile will be the first to be evolved on applying heat to the metal. This assumption may, however, be incorrect from considerations of the relative masses of the bodies."

Steel Forgings and Castings.—Both users and manufacturers of steel for large pieces have recently been devoting a good deal of attention to the question of how far steel castings are likely in the future to take the place of forgings of that metal or of wrought iron; and the same subject has received much and careful consideration from Lloyds' Committee and Engineer Surveyors, who have, indeed, recently made it a matter of special inquiry in different leading works throughout the country. Manufacturers like the Steel Company of Scotland and John Spencer & Sons of Newburn, have long undertaken the production of castings of a comparatively simple character with satisfactory results, and they are now applying their energies to the production of castings of a more difficult and complicated character.* An opportunity of examining the progress recently made in this direction was afforded at the North-East Coast Marine Exhibition opened at Tynemouth in September, when, among other exhibits the Steel Company of Scotland showed a segment of a circular rack for an iron-clad turret of 12 cwts.; a propeller blade, recessed to receive a brass plate on the back face; a three throw crank shaft of 8 cwts.; a gun trunnion of 11 cwts., &c.; while Messrs. Spencer & Sons, of the Newburn Steel Works, exhibited quite a variety of productions, including a cast steel crank disc, 6¼ tons weight, crank shafts, propeller blades, hydraulic cylinders, and parts of marine engines. The practicability of the manufacture of steel castings for marine purposes has been satisfactorily established in many ways; and Lloyds' surveyors, in a recent report to their Committee, have shown, by an elaborate series of tests conducted at the works of Hallside and Mossend in Scotland, and of Newburn and T. Vickers & Sons in England, that such castings may be produced even more reliable and altogether more suitable for their purpose than the forgings of wrought iron which, up to the present time, are almost universal in marine work. There are still, however, eminent authorities who hesitate to recommend steel castings, believing that in a structure so liable to strains as a crank shaft, for instance, it is necessary to put work into the manufacture, which would mean, of course, that steel, if adopted at all, should be forged either by the hammer or by hydraulic compression. Messrs. Cooke & Mylchreest of Liverpool have introduced a method of casting steel stern frames, &c., which, if found to answer in practice, would be likely greatly to simplify and probably also cheapen the cost of ship construction. A stern frame on this plan has recently been cast by Messrs. W. Jessop & Sons of Sheffield for a vessel under construction at Barrow. There are jaws cast on to the stern frame, and these are left open at the back so as to admit the rudder shaft, the space between the jaws and the shaft being then filled in with a gun metal bush, which drops into its place. Messrs. Jessop have cast several other stern frames on the same plan, one of them being 32 feet long by 14 feet 6 inches at the bottom, the section of metal being 9 inches by 4 inches.

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* Vide Mr. Riley's remarks on M. Pourcel's paper, p. 527, *ante*.

To determine the suitability of steel castings for the manufacture of crank shafts, on a system patented by Mr. Dickinson of Sunderland,* three series of parallel tests were recently made at the Newburn Steelworks with iron forgings, steel forgings, and steel castings. The bars of forged iron were obtained from a block taken from between the webs of a wrought iron crank shaft, passed by Lloyds, the cast steel from the material of the crank webs, cast at Newburn Works for Mr. Dickinson, and the forged steel from a double-throw crank shaft made under an eight-ton hammer and passed at Lloyds. The average maximum stress was found to be :—

Wrought iron	13·61 tons per square inch.
Cast steel	30·14 ,, ,, ,,
Forged steel	29·32 ,, ,, ,,

The average of the breaking stresses on the fractured areas was ascertained to be, for

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* In Dickinson's plan the crank pin and the two webs are formed together, and a flange resembling the half of a fan coupling is forged on the end of each piece of shaft adjacent to the crank. A recess is provided in each web into which one of the flanges fits, the whole being secured together by bolts.

Wrought iron	20·06 tons.
Cast steel	42·41 „
Forged steel	48·66 „

In lengths of five inches the average elongation of the specimen tested was :—

Wrought iron	13·35 per cent.
Cast steel	21·87 „
Forged steel	27·65 „

It is to be noted that the wrought iron specimens were not so sound as they should have been.

Steel for Welded Coils.—Sir W. G. Armstrong,* speaking of the application of steel to the manufacture of welded coils, stated that Dr. Siemens had some time ago supplied the Elswick Ordnance Works with a sample of mild steel specially prepared for this purpose. It was very low in carbon, containing only about 0·10 per cent. A test piece cut from the bar as it came from the maker showed the limit of elasticity, or point at which permanent stretch commenced, to be 13·5 tons per square inch, being not much greater than that of wrought iron; and it broke at 23·3 tons, showing that its ultimate strength was also very similar to that of iron; but its ductility was so great that it stretched to the extent of 37·5 per cent. of a length of 2 inches before breaking. A similar test piece tempered in oil had its elastic limit raised to 24 tons per square inch, and it broke at 28·6 tons per square inch, while its ductility remained nearly as before, the elongation being 36 per cent. instead of 37·5. It will be perceived, therefore, that the material was of a very fine quality, and if the results attained with the tempered specimen could have been realised in a welded coil, its superiority over wrought iron would have been very marked indeed. Two welded coils of equal dimensions were made from this material, and there was no appearance in either case of defect in the welding. Both of these coils were tempered in oil, and one of them was applied as a jacket to a steel cylinder closed at both ends, and used for the purpose of determining the pressure exerted by different charges of gunpowder fired in confinement. An exact duplicate of this cylinder was jacketed with a coil of wrought iron of the same dimensions as the steel one, and the two cylinders were used in comparison with each other. The cylinder with its steel jacket, however, began to stretch laterally under a pressure which produced no change in the wrought iron coil. The experiment was considered conclusive against the use of steel for welded coils, and no further attempt was made to use it for that purpose. The duplicate of this steel coil was laid aside, and Sir William's attention having been lately recalled to the subject, he applied himself to discover the cause of the inferiority displayed after undergoing the process of coiling and welding. He had a test piece cut from the coil in the lengthways direction of the bar of which it was made, and he found the elastic limit was only 12·5 tons per square inch, against 24 tons in the previously tempered test piece, while the breaking point was 19·1 against 28·6 in the former case. The loss of ductility was still more decided, the elongation being only 7·5 per cent. instead of 36 per cent. He then had a test piece cut across the welds, and this broke, not at a weld but through the solid, thus showing that the welding was perfect. In this case, the elastic limit was 12 tons per square inch, the breaking point 20·1 tons, and the elongation 6 per cent.

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* "On the Treatment of Steel for the Construction of Ordnance, and other Purposes," paper read before Section G, British Association Meeting, August 1882.

Trunnion Hoops for Bessemer Converters.—Converting vessels for the basic process of steel-making have recently grown to very considerable proportions, measuring over 10 feet diameter, and, when lined, frequently weighing 60 to 80 tons. To support in bearings and to turn over so large and so highly heated a furnace, containing its charge of 15 tons of molten steel, requires great care and precaution in construction, so that there may be no failure in any part of the apparatus. Hence it is deemed advisable to retain the trunnion piece (a very strong hoop going entirely round the vessel) in which the vessel rides at its ease, its iron casing and refractory lining being thereby relieved, as far as possible, from the various strains incidental to its suspension and to its turning motion. It being almost impossible to make such rings as wrought iron forgings, they were formerly made of cast iron, but that material is scarcely sufficiently trustworthy for the heavy work required. This has led Messrs. Henry Bessemer & Co., Sheffield, to produce such rings in cast steel, and the *Engineer* of August 25th gives a sketch of one of several trunnion rings in this material which have been lately cast by that firm for Messrs. Bolckow, Vaughan, & Co., of Middlesbrough. These rings are over twelve feet in diameter, and weigh upwards of sixteen tons each.

Open-Hearth Steel Manufacturing Practice.—The Steel Company of Scotland, at their Newton Works, recently turned out in one week 2200 tons of ingots from their 22 Siemens open-hearth furnaces, the largest out-put from a single furnace being 188½ tons. From the plate mill at the same works, 73 and 76 tons of slabs respectively were turned out in two successive shifts. At the Blochairn Works of the same company, with 12 furnaces, as much as 1566 tons of ingots have been turned out in a single week. One of the hammers at these latter works (which is spoken of nominally as an 8-ton tool) has in one week hammered into slabs for plates 625 tons of ingots, in the course of regular, steady work; but, when working under pressure, the same hammer has turned out 81½ tons of slabs in a single shift of 12 hours. No. 2 plate mill at the Blochairn Works has passed through in one week as many as 482 tons of slabs. In the course of one week, when the men made a spurt prior to finishing up their work for the Glasgow Fair Holidays, two consecutive shifts of hands, working 11 hours each, charged 91 tons, 13 cwts. and 95 tons, 16 cwts. of slabs respectively, the production in the shape of *sheared* plates being, in the one case, 73 tons, 6 cwts. and, in the other, 76 tons, 12 cwts.

Tar Bottoms for the Acid Process.—Mr. Tucker, of the Rhymney Iron and Steel Company, has successfully introduced the use of tar in place of water for mixing with the ganister for bottoms, the effect being to bind the particles of ganister together with a non-volatile and infusible cement of solid carbon. The mass so obtained becomes extremely hard on drying, and is well capable of resisting chemical action and mechanical abrasion. The average duration of these bottoms during a year's continual use is 18 with 9½ ton charges, and as many as 37 blows have been obtained. Pin hole bottoms made from the material have stood 16 blows.

Manufacture of Steel Forgings by the "Vickers-Siemens'" Process.—A report recently made to Lloyd's states that at the works of Messrs. Vickers, Sons, & Co., the steel is made by a process introduced by the firm, and called by them the "Vickers-Siemens" process. At the Bolton Iron and Steel Company, it is made by either the Bessemer or the Siemens process, according to the method preferred. By each of these firms the steel is first cast in large ingots, the lower portions (frequently only the lower third) of the ingots are then cut off, and from these portions the shafts are forged. Great importance is attached to thoroughly forging the material, it being considered at both of these establishments to be absolutely necessary to put a very great deal of mechanical work upon steel in order to render its ductility beyond question.

The principal difference between the practice of these two firms lies in the temper and composition of the steel employed. Messrs. Vickers, Sons, & Co. recommend only very mild steel, while the Bolton Company prefer steel having a tensile strength of from 28 to 34 tons per square inch as giving a better result, the working which they give the shafts while forging being sufficient to secure an amount of ductility which they consider to be ample.

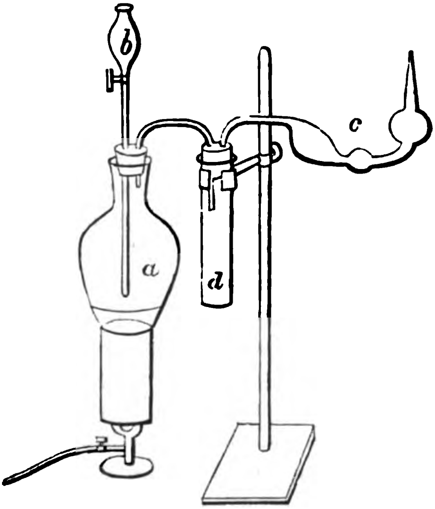
It is the practice of Messrs. Vickers, Sons, & Co. to cut one or two test pieces 12 inches long and 1¼ inch square from each solid shaft and from each part of every built shaft, and bend them under a drop testing machine, and, unless the pieces close together double without fracture, the shaft is not proceeded with. Another piece from each shaft is also tested for tensile strength.

In a crank shaft made at Messrs. Vickers' works for the s.s. *City of Berlin*, and which had recently broken at sea, the appearance of the journals showed clearly that the shaft had been running for a long time with the bearings out of line, and a close examination showed that the journal which had not fractured was flawed round its fillet. Four pieces were cut for testing out of this shaft. Two were tested by cross-bending and closed together without fracture, while the other two which were tested for tensile strength showed the material possessed an ultimate tensile strength of 23 tons per square inch with an elongation of 28 per cent. on a length of 10 inches, or of 30½ per cent. on a length of 8 inches. Although the steel was thus shown to possess a great amount of ductility, yet its endurance was not sufficient to withstand the great strains thrown upon it by running the shaft continuously with bearings out of line. That the flaw in it was not caused by local weaknesses of the steel, such as are supposed by some people to exist in large steel masses, is shown by the fact that the defects in the journals, and also one which was subsequently found in the crank pin, were in those places in which cross-bending produces the greatest strain, viz., in the fillets of the bearings.

IV.—*CHEMICAL PROPERTIES OF IRON AND STEEL.*

Estimation of Sulphur in Iron and Steel.—G. Craig, of Cumnock, N.B. (*Chemical News*, November, 1882), for well-nigh two years has been estimating sulphur in iron and steel by a modification of the evolution process, which consists of passing the evolved gases through an ammoniacal solution of peroxide of hydrogen, whereby the sulphuretted hydrogen is oxidised to sulphuric acid, the latter being estimated as usual. The *modus operandi* is as follows:—

A hundred grains of the iron or steel are placed in the 10 oz. flask (*a*) along with one-half ounce water; 1½ oz. hydrochloric acid are added from the stoppered funnel (*b*), in such quantities at a time as to produce a moderate evolution of gas through the nitrogen bulb (*c*), which contains one-eighth ounce (20 vols.) peroxide of hydrogen and one-half ounce ammonia. The tube (*d*) is to condense the bulk of the hydrochloric acid which distils over during the operation. When all the acid has been added, and the evolution of gas becomes sluggish, heat is applied and the liquid boiled till all action ceases. Air is blown through the apparatus for a few minutes, and the contents of *c* and *d* washed into a small beaker and acidified with hydrochloric acid, boiled, barium chloride added, and the barium sulphate filtered off after standing a short time. A blank experiment must be done with each new lot of peroxide of hydrogen obtained, which always gives under 0·1 barium sulphate.



The whole operation is finished within two hours, the usual oxidation process occupying nearly two days; and the results obtained are invariably slightly higher than by the oxidation process. Until lately the author has always added excess of chlorate of potash to the residue left in (*a*), evaporated it nearly to dryness, diluted, filtered, and added chloride of barium to the diluted filtrate, but only once has he obtained a trace of precipitate after standing forty-eight hours, and the pig-iron in that case contained 8 per cent. of silicon, so that all the sulphur is evolved during the process. It has been objected to the evolution process that when the iron contains copper all the sulphur is not evolved, but theoretically it ought to be evolved whether copper is present or not; and to test the point the author fused 3 lb. of ordinary Scotch pig-iron with some copper for half-an-hour in a Fletcher's gas furnace. No copper could be detected in the iron by mere observation with a microscope, but it gave on analysis 0·225 per cent. of copper, and on estimating the sulphur in it by the above process, and by oxidation with chlorate of potash and hydrochloric acid, using 100 grains in each case, and performing blank experiments, he found:—

By peroxide of hydrogen process	0·0357 per cent.
By oxidation ($KClO_3$ and HCl) process . . .	0·0302 „

so that even in highly cupriferous pig-iron all the sulphur is evolved on treatment with strong hydrochloric acid.

Sources of Errors in Determining Iron in Ores by the Stannous Chloride Method.—K. F. Foehr (*Berg-u.-Hütten-Zeitung*) states that this volumetric process has met with general acceptance, because it yields concordant results in a very short time. Nevertheless, it is not free from considerable sources of error, which, however, nearly compensate each other. The author shows that in the digestion of ferric ores a not insignificant portion of ferric chloride is volatilised. It may be easily shown that ferric chloride evaporates, even at 50°; if the digestion is performed in a small retort, more or less ferric chloride will be found in the receiver. This is still more the case at the boiling heat required for titration. This error, however, is compensated by a proportion of pyrolusite, as it is generally found in hydroferrite (bog-iron ore, &c.), and also in the hematites. On decomposing such ores with hydrochloric acid there is formed free chlorine, which is partly absorbed by the solution of ferric chloride, and can be entirely expelled only by prolonged boiling, which would lead to an increased loss of ferric chloride. In dissolving ferrous ores the case is the same, as they have to be first peroxidised by means of potassium chlorate or permanganate. Care must be taken that one of these sources of error does not too greatly exceed the other. The solution should be effected in flasks or beakers, and if the quantity of manganese peroxide present is in large quantity, it may be diminished by roasting.

A Rapid Method of Phosphorus Determination.*—At the Cleveland Steel Works of Bolckow, Vaughan, & Co., Mr. Cook has adopted a standard molybdate method of determining phosphorus, which is a modification of one adopted some years ago in the laboratory of Messrs. Pattinson & Stead, of Middlesbrough.† The method is thus described:—*Standard Molybdate.*—Made by dissolving 50 grms. of molybdate of ammonium in water, and making up to 500 c.c. Weigh 2 grms. of steel; moisten with hot water; dissolve in 7½ c.c. nitric and 15 c.c. hydrochloric acid; boil till clear, add water, boil, neutralise with ammonia, and then add 5 c.c. excess of ammonia. Boil the solution, and add nitric acid till neutral; then add 3 c.c. excess of nitric acid and 10 c.c. molybdate solution. Shake well, and allow the phosphate to settle in the beaker, which must be placed on a warm plate for ten minutes. When the supernatant liquid is clear, filter, wash three times with nitric acid water (1 to 50), and then dry the filter with the phosphate, brush the phosphate off the filter and weigh. Multiply weight by 50, and then by 0·0163 for percentage of phosphorus. The total bulk of filtrate and washings should not exceed 150 c.c.

The whole process can easily be done, and results obtained within an hour. It has been stated on several occasions that the molybdate acid process cannot give reliable results. In order to test this, Mr. Cook made a large number of analyses by both the magnesia and molybdic processes on the same sample, and the results, as will be seen on next page, were very concordant. When the phosphorus is very low, it is best to remove most of the iron before precipitating with molybdate, as the large excess of iron salt tends to prevent the separation of the phosphorus.

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* *Proceedings of the Cleveland Institution of Engineers*, June 1882, p. 182.

† Ibid., June 1882, p. 184.

No.	Magnesia.	Molybdate.	Checked by Second Chemist.
	Per cent.	Per cent.	Per cent.
1	1·58	1·58	...
2	1·49	1·50	...
3	2·00	1·90	...
4	0·516	0·52	...
5	0·620	0·624	...
6	0·196	0·196	0·199
7	0·058	0·059	...
8	0·053	0·059	...

Estimation of Sulphur in Pig-Iron (*Chemical News*, vol. xlvi. p. 236).—It is usual, in both methods of estimating sulphur in iron, to pass the hydrogen evolved by the solution of the metal in acid (usually HCl) through solutions in which the H_2S accompanying this hydrogen is converted into sulphides or sulphuric acid. Only insignificant quantities remain in the non-volatile residue of FCl_2, carbon, &c. This residual sulphur, however, as H. Rocholl shows, cannot be neglected if the iron under examination contains much *copper*. In some cases he obtained more than half of the S contained in cupriferous iron from the residue. The samples (10 grms. each) were in the usual way dissolved in HCl (50 c.c.), the hydrogen being passed through a five-bulb tube containing a solution of $AgNO_3$ in weak ammonia. The Ag_2S was separated and oxidised by Br water, the mixture filtered, and the filtrate precipitated by $BaCl_2$, when a portion of the sulphur (A) was obtained. The residue in the flask was likewise filtered, the solid portion (SiO_2,C, &c.) washed into a basin, evaporated, and then successively treated with HNO_3 and HCl, dried, re-dissolved, and filtered. From this filtrate, in all cases, a second

	Copper.	Total Sulphur.	Sulphur A evolved as H_2S.	Sulphur B contained in Carbonaceous Residue.	Sulphur B.
		Per cent. of Pig.	Per cent. of Pig.	Per cent. of Pig.	P. c. total Sulphur.
1. Cleveland pig-iron .	none.	0·075	0·069	0·006	8
2. Ordinary Bessemer pig	0·02	0·045	0·041	0·004	9
3. " " "	about 0·02	0·026	0·021	0·005	19
4. Cupriferous ditto .	0·20	0·065	0·050	0·015	23
5. " "	0·23	0·017	0·011	0·006	35
6. " "	0·26	0·061	0·029	0·032	52
7. " "	0·26	0·064	0·027	0·037	58
8. " "	0·26	0·026	0·009	0·017	65
9. " "	0·27	0·041	0·026	0·015	36
10. " "	1·09	0·071	0·046	0·025	35

precipitate was obtained by addition of $BaCl_2$, representing a second portion of sulphur (B). Finally the filtrate from the carbonaceous residue was diluted and mixed with $BaCl_2$ solution, when in no case, after several days standing, was a precipitate obtained.

The first three analyses, representing ordinary pig-iron, are only a few of many others giving similar results, sulphur B varying from 0·004 to 0·007 per cent.; Mr. Rocholl proposes an allowance of 0·004 per cent. as addition to the S, obtained by whatever method from the gaseous current. For cupriferous iron, however, a separate treatment of the residue is indispensable; the quantity of sulphur contained in it seems to depend as well on the total percentage of this element as on the quantity of copper present.

V.—*MECHANICAL PROPERTIES OF STEEL.*

Effect of Work on the Strength and Ductility of Steel.—At the Mossend Steel Works experiments have recently been made by cutting different pieces from the same ingot, and hammering or rolling them down by varying degrees, with a view to determine the effect of work upon the qualities of the metal. These tests show that while the cast steel, as cut from the ingot, has a strength of 23·6 tons per square inch, and a ductility represented by an elongation of 10 per cent. in a length of 8 inches, hammering it until its section is one-fourth of the original increases the strength to 32·1 tons and the elongation to 11 per cent., an increase of 36 and 10 per cent. respectively, while rolling it until its section is reduced to one-fifth of the original, increased the strength to 30·6 tons and the elongation to 23 per cent., an increase of 30 and 130 per cent. respectively. Ordinary plates rolled from the same charge to seven-eighths thick were found to have a tensile strength of about 27 tons per square inch, with an elongation of 26 per cent. in a length of 8 inches. The other experiments in which plates were reduced to ½ inch from thicknesses of ingot varying from 15 inches to 1 inch, showed little difference as regards tensile strength, but the ductility was greater in the cases in which the most work was put upon the material. The experiments, also, in which plates were worked down from various thicknesses of ingot slabs to ¼ inch thick, give similar results both as regards strength and ductility. While the different amount of work in rolling the plates from various thicknesses to either ½ inch or ¼ inch does not appear to have a marked influence upon the tensile strength, the operation of rolling from ½ inch to ¼ inch appeared to have a great influence, increasing the strength in every case from about 26 to 29 tons per square inch.

The Microscopical Examination of Metals.—*Engineering* (October 6th, 1882), after remarking that the chemical composition of metals can be partly now and probably will, as the result of further search, be more exactly ascertained by the microscope, and that graphite, chemically combined and mechanically mixed with iron, is readily distinguishable in its numerous and various forms, on an iron or steel surface, treated with weak solutions of acid, while if by the application of chemicals the surface can be so affected as to disclose other chemical components of the material when examined under the microscope, then a very ready method of examining materials has been established, which possesses great advantages over chemical analyses in simplicity and speed, proceeds to say that, finding the ordinary microscope ill adapted for this purpose, A. Martens has designed an arrangement which meets all its requirements. Ordinary microscopes are specially adapted for transparent objects of very small thickness, and the range of bulk admissible under them is generally extremely limited. Artificial light thrown on to the object, Mr. Martens considers in most cases unnecessary. He recommends, however, the use of lenses which admit of a distance from the object of about ⅜ in. Mr. Martens' microscope consists of an ordinary microscopic tube, fitted with suitable lenses of moderate power, and its only novelty consists in the manner of mounting it. It is held above the table by a knee-piece, fitted at each end with a large ball-and-socket joint, which can, by means of set screws, be fixed in any desired position, the final adjustment being effected by the usual rack and pinion arrangement. The table itself contains a large circular opening, and in it rests a half-sphere, the level surface of which serves as an object-table, while, by simply turning the sphere, the object can be brought into any desired position, so as to get the best inclination for both light and observation. To prevent this spherical table from sliding too freely, its surface is wiped over with a little tallow.

Effects of Drawing and Annealing Steel Wire.—Sir William Armstrong has found * that no form of steel is comparable, in respect of strength and toughness, to that which has been drawn into the form of wire or riband; and in the case of its application in that form to the strengthening of a cylinder, it has the additional advantage of admitting of being laid on with a more favourable adjustment of tension than is practicable with a solid hoop of considerable thickness. But even with wire, the best tensional condition for giving strength to a cylinder can only be approximately attained, owing to the fact, which is commonly overlooked, that in bending a wire over a cylinder it is impossible to give the proper degree of stretch to both of its sides. The outer side, having a larger circle to describe, must necessarily undergo greater elongation than the inside; and, in fact, unless the wire be laid on at a far higher strain than would be necessary or beneficial in the case of rings, the inside, acting as a fulcrum to stretch the outside, will assume a state of compression which can only be taken off by expanding the cylinder after the wire has been laid on. The thinner the wire the less will this disadvantage be felt; and for this reason a given area of section is much better in the flat, or riband form, than either round or square. Great additional strength is given to the steel wire by tempering in manufacture, and the highest strength is attained by passing the wire through the die as a final operation after the tempering process. The effect of this treatment is to put a very hard skin upon the wire, which, though greatly adding to the strength, is unfavourable for bending, and a very slight injury to the surface greatly conduces to fracture. Ductility is of paramount importance in wire that has to be rolled at a high tension on a cylinder, and, for this reason, wire tempered after instead of before finishing is safer, though not so strong. If the wire be thick, judicious annealing, though it lessens the ultimate strain which the wire will bear, raises in a very marked degree the limit of elasticity. Sir William has found that steel wire of about 0·2 in. thick, of great ultimate strength, began to stretch permanently at a tension as low as 25 tons per square inch, while, after being properly annealed, it would bear 35 tons before permanent movement. The explanation of this curious fact is probably to be found in the removal by the annealing process of the contending state of tension produced by the drawing or tempering on the inner and the outer portions of the wire. This view is enforced by the fact that when the thickness of the riband was reduced to somewhat less than half, this advantage of the annealing process almost wholly disappeared, and the wire was simply softened, or rendered more ductile. Castings of steel, unhammered, are improved by being tempered in oil in much the same degree as the forged material. Test pieces from a cast trunnion of steel gave the following results:—

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* Paper read before Section G, British Association, August 1882.

Before tempering the elastic limit was 16 tons, breaking load 27·8 tons, elongation in 2 in., 7·5 per cent. After tempering E.L., 25 tons; B.W., 37·7 tons; Ex. 12·5 per cent.; showing a great improvement under every head. The quantity of combined carbon contained in this specimen was 0·36 per cent. The objection to the use of cast-steel in the unhammered form is that it is liable to unsoundness from air bubbles. This, in Sir William's opinion, ought not to exclude its use for trunnion rings, which, from their peculiar form, can only be very imperfectly forged. The unsoundness from this cause would be greatly mitigated by casting under pressure, as advocated by Sir Jos. Whitworth. There is much less sacrifice of ductility or toughness when increase of strength is obtained by tempering than by increase of carbon; and, in fact, the advantage of tempering in oil is so apparent, both in the case of steel castings and of steel which has been either rolled or forged, that there are strong inducements for engineers to avail themselves of the process for increasing the efficiency of the material in nearly all its applications. The saving of the weight of material necessary for a given purpose would amply repay the cost of the tempering, and in the case of bridges of great span, where the strains are chiefly due to the weight of the structure, independent of its load, the economy effected would be far more than proportionate to the increase of tensile strength in the material.

The Structure of Iron and Steel.—Dr. H. C. Sorby, F.R.S., speaking of "The Microscopical Structure of Iron and Steel," * said he was first induced to investigate this subject with regard to the structure of meteoric iron. Little or nothing was known of the minute structure of iron and steel, but much might be learned of the nature of these metals by artificial fractures, although such fractures showed more the lines and planes of weakness, and the divisions between the constituent crystals, than the actual structure of the crystals, and their relation to one another. It was therefore requisite to devise some means of ascertaining the exact structure of the metals, independent of any lines of weakness revealed by fractures. The lecturer described the manner in which he sought to ascertain the exact structure of the metals, and said that as far as could be learned from the careful use of the microscope, various kinds of iron and steel contained at least seven well-marked constituents. In the first place, there was pure iron, and what were probably three well-marked compounds of iron, with varying amounts of carbon or other substances met with in small quantities in different sorts of iron and steel; portions of included slag, well marked crystals of graphite, and small crystals, which might be silicon. The lecturer then proceeded to exhibit, by means of the oxy-hydrogen lamp, a considerable number of illustrations of the structure of various descriptions of iron and steel, some being photographed by Mr. Charles Hoole direct from the preparations, others from drawings by the author, and others from nature prints, made by the process already referred to. Commencing with various kinds of cast iron, it was shown that their structure was sometimes largely modified by the presence of crystalline plates of graphite, over which was deposited what was probably free iron, and the interspaces filled by what were probably two distinct compounds of iron and carbon. In other cases, the structure was mainly dependent on the crystallisation of the iron itself, the graphite being thrown off towards the close of the process. In the case of white refined iron, the principal constituent was probably an intensely hard white refined iron, with much carbon, associated with which were one or more of the other compounds of iron and carbon present in grey iron. The microscopical structure of this white iron was exceedingly curious and beautiful. The next illustrations were of various kinds of wrought iron. The hammered bloom was shown to consist of an irregular mixture of crystals of iron and portions of slag. When rolled out into a bar, those portions of slag not squeezed out were thrown out into long threads. The crystals of iron seen in the bar were not, however, the original crystals of the bloom, but crystals formed on the cooling of the bar, since they exhibited little or no tendency to elongation in the line of the length of the bar, as would occur if the original crystals were drawn out by the process of rolling. The fibre seen on fracturing such specimens of wrought iron was mainly due to the elongation which occurred during the fracture, and was not a characteristic of the unaltered iron.

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* Lecture delivered at the Firth College, Sheffield, October 20th, 1882.

The Preservation of Iron and Steel from Rust.—Since a paper was read before the Institute on "The Preservation and Onamentation of Iron and Steel Surfaces,"* by Mr. George Bower of St. Neots, considerable progress has been made in getting the process then described into practical work—more especially on the Continent. Large works are already in operation in Paris, and several have been, and are being, erected in different parts of Germany, and the process is also now being introduced into the United States. A company was formed in England called "The Bower-Barff Molten Iron Company, Limited," who determined only to erect for themselves a model furnace, and for the first year to grant agencies and licenses on royalty. Several agencies and about a dozen licenses have already been granted, so that goods can now be treated in different parts of the country.

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* *Journal*, No. II., 1881.

It has been found that by first coating iron with magnetic oxide, enamelling may be performed at much less cost than by the cheapest of the best ordinary methods, and some beautiful work of this kind has been executed in France, Germany, and England. The French Company are using the process very extensively for railway work, and also as a base for decorative ornamentation. Iron, with them, is fast taking the place of the more expensive metals. Platinum and gold, as well as bronzes, are all deposited direct upon the magnetic oxide, to which it permanently adheres.

A very pretty mode of coating magnetic oxide with other metals has been patented by Mr. Bower—one which is specially applicable to such articles as stoves, fenders, panels, and small ornamental cast-iron ware. Magnetic oxide is composed of one equivalent each of prot- and peroxide. When formed on iron it is to some extent gritty and porous, and, taking advantage of this condition, Mr. Bower uses brushes formed of metallic wires of different kinds, and applies them briskly, either by hand or power, to the coating of magnetic oxide, when the surface is covered with a thin film of the metal of which the wire is composed, whether it be of copper, brass, nickel, bronze, or other metals, and the result is beautiful in the extreme. The silvery grey of the surface of magnetic oxide is lighted up to great effect, when the prominent parts are tipped with the shining film of metal left on them, by simply using the metallic brush in the same way as a black lead brush is used. It is a little curious that there is a bloom on the magnetic oxide when the articles first come out of the furnace like the bloom on a ripe black plum, which, when oiled over, lays bare the blue black magnetic oxide underneath. In Germany, it is the rule to dip the articles while still hot into oil, so as to fill up the pores of the oxide, and to form, when dry, a sort of elastic covering which preserves the oxide from abrasion. The cost of the process having been much reduced, and the difficulties connected with it having been surmounted, there would seem to be no reason now why it should not take its place as an industry very likely to render an important service in the development of iron and steel for constructive and decorative purposes, to which, because of their tendency to rust, they have not hitherto been applied.

Effect of Re-Heating Steel after Tempering in Oil.—With a view to ascertain whether steel cylinders, which have been tempered in oil, could be re-heated sufficiently for the purpose of shrinking upon a gun without destroying the effect of the tempering, a test piece cut from a tempered lump of steel was heated by Sir W. Armstrong* in melted zinc to a temperature of 750°, and then allowed to cool naturally in air. Comparing its resistance with the piece which had not been re-heated, it gave 25 tons per square inch, against 28 tons before stretching, and 40·2 against 43 tons before breaking; but its ductility was increased from 16 per cent. to 20·5 per cent.; so that, although rendered slightly inferior in strength, it was rendered more ductile and tougher by the re-heating. Similar experiments made with steel rather lower in carbon showed that the effect of re-heating to this temperature was almost inappreciable, either in the way of improvement or the contrary, and no degree of sudden cooling from so low a temperature had any distinct effect. On carrying the re-heating to still higher degrees, the effect of the previous tempering gradually diminished, but was not altogether obliterated, even when the temperature was raised to the bright red heat at which the rapidly cooling steel had been immersed in the oil. The friability of the steel at a welding temperature became more marked as the percentage of carbon was increased. Steel with 0·41 carbon, like milder samples, suffered very little from being merely heated to the welding temperature, provided that while so heated it was not disturbed by hammering. But it was so friable at that temperature that it broke into a mass of small crumbs under a moderate blow of the hammer. It was remarkable, however, that the same blow of the hammer which detached them from the block united them in a thin cake on the anvil. Whether the friability at a high temperature can be corrected by combining these materials with it is a point upon which Sir William's experience casts no light.

Effect of Rolling Steel.—Sir W. G. Armstrong,† asserts that mild steel is enormously increased, both in strength and toughness, by being drawn out either by rolling or hammering, but especially by rolling, which is more uniform in its action than hammering. There can be no doubt that the process of rolling steel tires may be extended to the production of rolled hoops of great width, and the time may not be distant, Sir William thinks, when in this manner continuous unwelded cylinders for boiler-making purposes may be made. Steel cylinders thus made and tempered in oil will be in a highly favourable condition for the construction of ordnance, but in order to make them available for longitudinal as well as for lateral strength, it will be essential to have them in much greater widths than existing machines are competent to produce. All ductile metals derive additional strength by being stretched, but steel does so in a pre-eminent degree. Roughly speaking, its modulus of elasticity may be taken as equal to $\frac{1}{1000}$th of an inch per foot for every ton per square inch of tension. This measure of elasticity applies equally, or nearly equally, to all kinds of steel, but the range of elasticity becomes greater as the strength is increased. Thus, steel that will bear 20 tons with permanent stretch, will retract $\frac{2}{200}$th of an inch per foot of length on being released from its load; while steel that will bear 40 tons without permanent stretch, will recover $\frac{4}{100}$th of an inch per foot on the removal of the strain. So, also, if the weaker specimens which recover only $\frac{2}{100}$th of an inch be stretched to a point at which it will sustain 40 tons per square inch, it will be exactly in the same condition in regard to elasticity as the stronger specimen which bore that load in the first instance—that is to say, its range of elasticity will be doubled. This is a very valuable quality, enabling steel to gather strength as it yields to an important increase of load.

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* Paper read before Section G, British Association, August 1882.

† *Ibid.*

The Increase of Tenacity in Perforated Test Bars of Steel and Iron.—A paper on this subject by T. Wrightson[*] is an amplification of observations already reported.[†] Further experiments have been made by the author, one upon a 2-inch by ½-inch Tudhoe bar, which, having tested it without perforation, he found to break at 28·73 tons per square inch of fractured area, and 22·68 tons per square inch of original area. He then took test pieces cut from the same bar and perforated them thus:—

No. 2, with one 1-inch hole in centre.
No. 3, with two ½-inch holes ,,
No. 4, with three ⅓ inch ,, ,,

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[*] Read before the Mechanical Section of the British Association at Southampton, August 1882.

[†] *Journal of the Iron and Steel Institute*, No. I., 1882, p. 47.

The results are given in the appended table, and show an increased strength per square inch, whether taken on the original or on the fractured area:—

No. of Test.	Description.	Original Area.	Ultimate Stress per sq. inch of Original Area.	Fractured Area.	Stress per sq. inch of Fractured Area.
1	2-inch by ½-inch flat bar .	0·9006	22·68	0·7118	28·73
2	2-inch by ½-inch do., with one 1-inch hole . .	0·497	22·98	0·3864	29·503
3	2-inch by ½-inch do., with two ½-inch holes . .	0·4584	24·82	0·3666	30·04
4	2 inch by ½-inch do., with three holes ·333 diameter	0·48015	24·99	0·3719	32·26

The author claims that these facts show conclusively that the form of a test bar may be such as to bring into action the cross and diagonal fibres of the material, so as to affect very considerably the results obtained.

VI.—*USES OF STEEL, &c.*

Compound Armour Plate Experiments.—Major O'Callaghan, R.A. (*Proceedings of the Royal Artillery Institution*, May 1882, p. 89), describes some recent experiments with an armour plate at Shoeburyness. The plate was manufactured by Messrs. J. Brown & Co. of Sheffield, measured 10 feet by 5½ feet by 11 inches, and was composed of about 7 inches of iron, faced by about 4 inches of steel, welded together by the process known as Ellis's patent. This process may be roughly described, by stating that a wrought-iron plate, rolled in the usual manner, is brought to a welding heat, and then covered with a layer of molten steel, which is poured on to it, and retained by a wall of wrought-iron surrounding the plate, after the manner of an open mould. When the mass is sufficiently cool, the double plate thus formed is rolled again, and its thickness considerably reduced. By this means, a weld between the two metals of extraordinary tenacity is produced. In no instance has firing at the plate effected their separation. In this particular instance, the usual *modus operandi* was departed from, and the molten steel was poured between the wrought-iron backing and a face-plate, about 1 inch thick, of rolled steel. Both steels were precisely the same in composition, and contained the same amount of carbon, *i.e.*, 0·75 per cent. A large layer of steel was found to have come away from the front in the region of the indents made by the 9-inch projectiles, disclosing a very curious configuration of the steel around these depressions.' It is suggested that this strange phenomenon throws some light on an appearance which has given rise to some speculation in former rounds fired at steel-faced armour plates.

It has always been observed that a wedge-shaped layer of steel is apparently separated radically round the indents, and, in early experiments, it was thought that a thin part of the steel face, the absolute uniformity of which cannot always be guaranteed, had been struck. The frequency of the appearance, however, negatived the theory, and the denuding of this plate seems to show what probably happened in other instances: the wedge-shaped layer of steel being, in fact, a portion of the surface or covering of the "craters" now removed.

Steel v. Wrought Iron for Armour.—Captain C. Orde Browne (*Proceedings of the Royal Artillery Institution*, February 1882), after premising that whether a ship's armour can be attacked by any given gun with advantage or not, depends on the nature and thickness of her armour, proceeds to say that steel distributes the shock of impact through its mass, and hence it has great power in resisting a single blow, but it is liable to succumb to the continued fire even of inferior guns. No better illustration of this could be given than the comparative behaviour of the twenty-two inch steel and iron plates at Spezzia in 1876. The steel crumbled away gradually, even under the fire of ten-inch guns,—a fire which proved almost harmless to the twenty-two inch wrought iron plates. On the other hand, the steel completely stopped the projectile of the hundred-ton gun, which enormously outmatched it. This it did at the expense of the plate itself shivering into fragments, while the iron allowed this projectile to pass completely through it. Both experiments were repeated with the same results. Penetration through steel is, therefore, hardly to be looked for, but rather the shattering of it. The 9·45-inch Krupp B. L. gun, firing a shot weighing 348·3 lbs., with a velocity of 1890 feet per second, can, according to Colonel Inglis, penetrate a plate 18·1 inches thick. The 38-ton gun, 11·5-inches calibre, firing a shot weighing 812 lbs., can penetrate a plate 17·9 inches thick only. That is to say, of the two the Krupp gun has rather the advantage in penetrating wrought iron. On the other hand, the 38-ton gun-shot has about

12,260 feet tons stored-up work, whereas the Krupp gun has only 8630 feet tons work. Consequently, while the latter gun would be equal or slightly superior to the former if fired against iron, two rounds of the former would probably produce nearly the same effect as three rounds of the latter against steel plates. It appears reasonable to suppose that the cracking of the steel represents the stored-up work in the shot as fully as the shearing effected in the wrought iron; although, in so curious a mechanical problem as the cracking and breaking up of steel, which goes on for some minutes after the moment of impact, it is unsafe to dogmatise. One conclusion arrived at by the Sub-Committee on Plates and Projectiles is, that it is necessary to attack steel-faced armour with steel projectiles; the fact being that chilled iron, under the sudden resistance experienced, breaks up before the conditions favourable to its success are established.

Steel-faced armour, that is, armour composed of a wrought iron foundation plate and steel-face plate, comes under the heading of steel in a modified form; not that a plate composed of a compromise between steel and wrought iron would answer, for the object is to have a hard surface and tough back. Compound armour, however, so far behaves like steel that it is seldom fairly penetrated, but generally destroyed by fracture. It has recently exhibited great powers of resistance.

Wrought iron yields locally at the point of impact only. It is universally admitted that for direct fire a sharp-pointed projectile is best. This forces in its sharp point, which experiences comparatively slight resistance at first, and soon gets deep enough to cause the plate to begin to yield at the back, just opposite to the shot's point, in a star or cross-shaped tear, which is opened; the corners bending back as the shot gets deeper, until at length the projectile forces its way through, mainly by tearing the iron in lines, whose lengths are directly proportional to the calibre of the gun.

Steel for Struts and other Members of Bridges.—B. Baker's experiments * are claimed by the author to prove that steel is far superior to iron as a material for struts, although the superiority is not so great as when tension members are in question. Thus the Forth Bridge struts will be from 30 to 40 per cent. stronger in steel than in iron, whilst the tension members will be about 50 per cent. stronger. It does not follow that the steel strut would not be 50 per cent. better also as regards actual work, which is very different to what takes place in a testing machine. A steel or an iron rail, tested for transverse strength in a machine, will, as a rule, bend many inches, and fail by distortion of the head under the compressive stress. In actual work hundreds of such rails break, but it is the tensile and not the compressive stress which causes the failure, and there is no distortion of the head as in the testing machine. Similarly, when riveted girders break under traffic, it is not the top flanges with a calculated stress on the average of about one-third of the ultimate resistance that give way, but the bottom members, where the calculated stress is only about one-fourth of the ultimate resistance. In short, the universal experience is, that fatigue is far more injurious to iron or steel under tensile than under compressive stress, and it follows that the factor of safety should not be the same in the two cases. This is quite consistent with ordinary practice, for probably the majority of girder bridges in this country have equal-sized top and bottom flanges, which, after allowing for the riveting, would give a factor of about three for the compression, and about four for the tension members respectively.

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* Paper on "The Forth Bridge," read before Section G at the British Association.

The peculiarities of steel are tolerably well understood now, and amongst other precautions it is especially desirable to so design the joints in tension that no tearing action shall be set up along a line of rivet holes. Accidents of workmanship necessitate the provision of a good factor of safety in steel joints in tension; but, after watching the testing of many steel tubes under compression, the author cannot conceive any accident of workmanship which could bring about the failure of steel-tubes such as those in the Forth Bridge, even if the working stress was raised to two-thirds, instead of about one-fourth of the ultimate resistance. In fine, he believes a steel tube to be the most trustworthy member which could be introduced into a great and important work.

Some time ago the author made some experiments on steel which had been previously subjected to end pressure in a tube, so that flexure could not occur. The rods were one inch diameter by 30 in. long. With the mildest steel, the resistance to flexure was 14·5 tons per square inch in the uncompressed rods, and 22 tons, or say 50 per cent. more, in the rods which had previously been subjected to an end pressure of 36 tons per square inch. With somewhat harder steel, the corresponding figures were 16 tons in the uncompressed, and from 26 to 29 tons in the previously compressed bars—a gain of from 60 to 80 per cent. The bars, when tested in tension, showed no loss in strength or elongation from the previous compression. As 30-ton steel, after the end pressure had been applied, bore as much load without flexure as 54-ton steel which had not been so treated, it is clear that the adoption of mild steel in railway-bridges would be much accelerated if some simple practical method could be devised for bringing about the molecular change effected in the above instances by an end pressure.

The Forth Railway Bridge.—In a paper * dealing with the materials to be used in this important structure, B. Baker states that the total length of the great continuous girder is 5330 ft., or say one mile, and of the viaduct approaches, 2754 ft., or rather over half a mile. There is nothing calling for special remark in the viaduct. The piers will be of rubble masonry, faced with granite, and the superstructure of iron lattice girders with buckled-plate floor and trough rail bearers, as in the instance of the main spans. The main girders, spaced 16 ft. apart, will be placed under the railway, and there will be a strong parapet and wind screen to protect the trains. The central girder has a depth of one-seventh of the span, whilst the cantilevers may be looked upon as halves of a girder having a depth of one-fourth of the span. Exceptional depths like these confer exceptional stiffness, and there is the additional fact that the live load of a passing train will be quite insignificant as compared with the dead load of the structure. The heaviest train traversing the bridge will not deflect the 1700 ft. girder more than 4 in., which is considerably less than the deflection of the 460 ft. span of Saltash Bridge under its test load, whilst a wind pressure, equivalent to 30 lbs. per square foot over the entire 1700 ft., would bend the bridge laterally less than 9 in. About 42,000 tons of steel will be used in the superstructure of the main spans, and 3000 tons of wrought iron in that of the viaduct approach. The total quantity of masonry in the piers and foundations will be about 125,000 cubic yards, and the estimated cost of the entire work, upon the basis of the prices, at which the original suspension bridge was contracted for, is about £1,500,000. Owing to the varying price of steel, and to the magnitude and novelty of the undertaking, this estimate must be taken as approximate only, as no contract has yet been concluded for the works.

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* Read before Section G of the British Association, August 1882.

VII.—*MISCELLANEA.*

Boiler Explosions in 1881.—The 20th annual "Report and Record of Boiler Explosions," by E. B. Marten, Stourbridge, chief engineer to the Midland Steam Boiler Inspection and Assurance Company, states that during last year there were 33 boiler explosions in the United Kingdom, by which 41 persons were killed and 51 injured. The highest number occurred at collieries and mines. Ironworks followed next with a total of 8, and the remainder were divided amongst mills, docks, brickyards, quarries, and other places. During the same year there were no fewer than 34 explosions of domestic boilers or steam-pipes, by which 10 persons were killed and 20 injured. In these cases the majority of accidents occurred through over-pressure, produced principally by frost.

A Single-Lever Testing Machine.—Mr. J. Hartley, Wicksteed (*Proceedings of the Institution of Mechanical Engineers*, August 1882), described a testing machine of this description, in which several new features are introduced, including the travelling of the weight beyond the fulcrum on to the short end of the lever, till a point is reached where the long end is balanced; the arrangement of a non-pendulous travelling weight, of which the centre of gravity moves along a centre line drawn through the point of support and the point of attachment of the sample; and the indifferent equilibrium of the whole, which is attained by arranging the weight of the lever and all its attachments symmetrically above and below this centre line.

This machine has been specially designed for testing samples of iron and steel up to 2 ft. long, which comprises the great bulk of practical testing work. Several gentlemen who had seen the machine at work spoke very highly of its merits.

Technical Education in London.—The programme of Technological Examinations for the session 1882–83 of the City and Guilds of London Institute has just been issued. A difficulty in obtaining good technical teachers appears to be still experienced by the Institute; and in the new programme some relaxation may be noted in the stringency of the conditions under which persons are to be registered as teachers of technology. Any person who is engaged in teaching science under the Science and Art Department, and who gives evidence of having acquired in the factory or workshop a practical knowledge of his subject, may now be registered as a teacher. The Central Building, the first stone of which, in Exhibition Road, was laid by the Prince of Wales, is rapidly approaching completion, and will, it is expected, increase the supply of competent technical instructors. The Institute holds examinations in 42 different subjects. The syllabuses of these subjects have been carefully revised, and the lists of works of reference appended to them have been in many cases supplemented by notices of books which have been published during the past year.

The Work of the Patent Office in 1881.—The report for the past year of the Commissioners of Patents states that the number of applications for letters patent during the year 1881 was 5751, being an increase of 234 upon the previous year. Of these, 1871 were for various reasons suffered to lapse, and the number which came into force was thus 3880. The law is that all patents granted are subject to the condition that they shall be void at the end of three and seven years respectively, unless there be paid before the expiry of those periods stamp duties of £50 and £100 respectively, and a table in the report shows that nearly 30 per cent. of the patents that had become valid between 1852 and 1881 paid the third year's stamp duty of £50, and about 10½ per cent. paid the seventh year's duty of £100. The revenue of the Patent Office in 1881 exceeded the expenditure by £163,442.

Large Slotting Machine.—A slotting machine, specially designed for marine engine work, has recently been completed by Messrs. Craven Brothers, of Manchester. The weight of the machine is 70 tons, and the maximum stroke of ram 10 ft., with a minimum stroke of 9 inches. The distance from the face of the ram to the frame is 6 ft. 6 in., and the total height from ground line, when working its longest stroke, is 30 ft. The machine can be worked at equal speed in the cutting and return strokes, or the return stroke may be accelerated to double that of the cutting stroke when the work will admit. The self-acting motions are all variable from 4 to 64 cuts per inch, and besides these, the slides and rotary table can be moved in either direction by power at the rate of eight feet per minute.

Improved Railway Spring Making Machine.—An improved tool for manufacturing railway springs has been constructed by Messrs. Wm. Collier & Co., of Manchester, for the Lancashire and Yorkshire

Railway Company. By an ingenious arrangement this machine, in a compact form occupying not more than about 9 ft. by 6 ft. 6 in., combines all the processes of shearing, tapering, shaping, punching, slotting, and nibbing. It consists of an upright frame carrying three slides in the centre, working respectively to a couple of dies for pointing the spring ends and putting on the nibs, and a punch for cutting the horizontal slot. A fourth slide works to a circular punch for the centre bolt hole, and above this a pair of shears for cutting the steel bars to the requisite length is carried at one end of the machine, and at the other is a pair of rolls—the bottom roll grooved to prevent the widening out of the metal under pressure and running eccentric—for tapering the end of the springs. The machine is driven by ordinary gearing, and is operated by one man.

Lathe for Ordnance Work.—Messrs. Hulse & Co., of the Ordsal Iron Works, Manchester, have in hand a lathe for ordnance work, which when complete will weigh upwards of 100 tons. Several new features are being introduced into this lathe, the principal of which are in connection with the means for traversing the slide rests by the introduction of non-rotating screws, with rotating nuts.

Mill for Rolling Boiler Rings Hot.—Messrs. De Bergue & Co., of Manchester, have in hand a new angle and T iron horizontal rolling mill for rolling boiler rings hot. The machine consists of three rolls working on the top of a large table, and capable of making rings from 15 in. up to 6 ft. 8 in. diameter, and the gearing and driving power are all beneath the floor of the shop. In connection with the new riveting machine with yielding pillar recently brought out by Messrs. De Bergue, the firm have adopted a dead-weight balance arrangement in the place of the hydraulic power at first introduced.

Utilisation of Bye-Products in Manufacturing Coal Gas.—In his Presidential Address to the members of the British Association,* Dr. Siemens made some remarks relative to the utilisation of bye-products in the manufacture of coal gas, which are of interest in view of the efforts now being made to utilise the tar and ammonia lost in the coking of furnace coal.

Regarding the importance of the gas supply as it exists at present, a Government return shows that the capital invested in gasworks in

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* Southampton, August 1882.

England, other than those of local authorities, amounts to £30,000,000; in these 4,281,048 tons of coal are converted annually, producing 43,000,000 cubic feet of gas, and about 2,800,000 tons of coke; whereas the total amount of coal annually converted in the United Kingdom may be estimated at 9,000,000 tons, and the bye-products therefrom at 500,000 tons of tar, 1,000,000 tons of ammonia liquor, and 4,000,000 tons of coke, according to returns furnished to Dr. Siemens by the managers of many of the gasworks and corporations. To these may be added say 120,000 tons of sulphur, which up to the present time is a waste product. The colour industry utilises even now practically all the benzene, a large proportion of the solvent naphtha, all the anthracene, and a portion of the naphthaline resulting from the distillation of coal tar; and the value of the colouring matter thus produced is estimated by Mr. Perkin at £3,350,000. The demand for ammonia may be taken as unlimited, on account of its high agricultural value as a manure; and considering the failing supply of guano and the growing necessity for stimulating the fertility of our soil, an increased production of ammonia may be regarded as a matter of national importance, for the supply of which we have to look almost exclusively to our gasworks. The present production of 1,000,000 tons of liquor yields 95,000 tons of sulphate of ammonia; which, taken at £20, 10s. a ton, represent an annual value of £1,947,000. The total annual value of the gasworks' bye-products may be estimated as follows:—

Colouring matter	£3,350,000
Sulphate of ammonia	1,947,000
Pitch (325,000 gallons)	365,000
Creosote (25,000,000 gallons)	208,000
Crude carbolic acid (1,000,000 gallons)	100,000
Gas coke 4,000,000 tons (after allowing 2,000,000 tons consumption in working the retorts) at 12s.	2,400,000
Total	£8,370,000

Taking the coal used, 9,000,000 tons at 12s., as equal to £5,400,000, it follows that the bye-products exceed in value the coal used by very nearly £3,000,000. In using raw coal for heating purposes these valuable products are absolutely lost.

Metallurgical Studies at King's College, London.—A medal and prize, of the annual value of twenty guineas, called the Siemens Gold Medal and Prize, has just been founded at King's College by

Mr. Charles William Siemens, D.C.L., F.R.S., "with the object of stimulating the students of King's College, London, to a high standard of efficiency in metallurgical science. It is open to those who have, as matriculated students, studied in the applied science department for two years, and who, either in their third year, or, if they remain in the department for three years, in the succeeding year, make metallurgy a special study. The first award will be made at the end of June 1883, and will depend partly on an essay on some particular subject, partly on a written examination on the metallurgical lectures, and partly on actual work done in the laboratory. The subject for the essay for 1883 will be the "Manufacture of Steel suitable for Ship and Boiler Plates." The essays are to be illustrated by free-hand sketches and mechanical drawings to scale, and must be sent in to Professor Huntington on or before June 30th next year.

THE
IRON AND STEEL INDUSTRIES
OF
FOREIGN COUNTRIES
IN 1882.

SECTION II.—1882.

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AMERICA—UNITED STATES.

A.—METALLURGICAL TECHNOLOGY.

I.—*ORES AND FUEL.*

Charcoal Kilns.—John Birkinbine (*Proceedings of the American Institute of Mining Engineers*, August 1882) states that in the United States the production of charcoal is successfully carried on both in kilns and retorts, and the acetic vapours arising from the carbonisation are condensed and made into commercial products. There are now in operation at the Bangor Furnace, Michigan, 14 kilns of 80 cords capacity, in which 16,000 cords of wood are annually carbonised, and the Elk Rapids Furnace, Michigan, also has 22 100-cord kilns, in which 40,000 cords of wood are each year converted into charcoal, the acetic vapours being exhausted from all these kilns by Pierce's patent method, and converted into acetate of lime and 250 gallons of alcohol. In addition the Elk Rapids Furnace has three 100-cord kilns and ten 60-cord kilns which are not constantly in use. That the charcoal is not deteriorated by the collection of the acetic vapours is proved by the reports of the managers of these plants, and by the remarkable records made by both these furnaces. It is doubtful if any other charcoal blast furnace in the country can show as good work for four consecutive years as Bangor. Concerning the question above referred to, Major Picklands, the manager, says, "We do not extract acetic vapours; nature throws them off from the wood in process of carbonisation, whether that process takes place in a kiln, retort, or dirt pit, and we capture the vapours and utilise them." The financial success of the chemical department at Bangor encouraged the more pretentious venture at Elk Rapids, and late reports from the latter furnace place it in the front rank for economical fuel consumption and large output.

Value of Petroleum as a Fuel.—The *Railway Gazette* of April 14th states, that although many attempts have been made to utilise a substance which is apparently so valuable a means of heat production, none of the schemes for making iron or running locomotives with this fuel have ever proved financially successful. The cause of this is simply the fact that there is more heat-producing power in a dollar's worth of coal than in a dollar's worth of petroleum. This amount is taken as being 444 lb. anthracite, giving 6,005,544 heat units; 421 lb. bituminous coal, giving 6,510,765 heat units; or 103 lb. petroleum, giving 2,182,766 heat units. Practically, however, from 15 to 25 per cent. of the heating power of the coal is not utilised. Therefore, if it were possible to consume petroleum thoroughly, so as to develop the whole of its theoretical heat-producing power, this difference would be considerably diminished. It is not considered probable that the cost of petroleum will be so reduced, and that of coal so increased, as to bring the two substances on to the same footing; but even if that were to be the case, the enormously increased demand for petroleum, resulting from its use as fuel, would inevitably tend to re-establish the difference in favour of coal. The advantages of petroleum—freedom from smoke and cinders, and the much smaller space required for its storage—are not likely to counterbalance its great cost.

Coal Mining Machines.—D. R. Jones, the President of the American Miners' Union, states that the coal-mining machines lately introduced into Rend's mines, Panhandle, are so far successful, and are running night and day. The engineer, or person in charge of the machine, receives $2.50 a day. The helper, whose duty it is to assist in its moving, and to shovel away the bearing-in slack, receives $2, and the loaders 40 cents per ton for loading cars, taking down shale, and keeping the rooms in order. Two shifts of men are employed, working from six to five in the daytime, and from six P.M. to five A.M. Whether taking it for a year the mining of coal with machinery will prove successful, is, says Mr. Jones, "an interesting question to the miners and the community. If the experiment is a success, machines will be introduced sooner or later into all the mines, and the present system of mining be revolutionised."

Chrome Ore.—The *Iron Age* announces that the mining and shipping of chrome ore from Placer county, California, is said to be assuming considerable dimensions, and is becoming an important industry. Chrome deposits not yet opened are known to exist in many other places in the country, and their development would give profitable employment to large numbers of men.

Coal and Iron in West Virginia.—The *Philadelphia Record* states that the elements of wealth and prospective growth for the Kanawha Valley are found in its immense deposits of coal and iron ore, and the products of its forests. The output of coal is rapidly increasing both by shipment east over the Chesapeake and Ohio Railroad, and by barges down the Kanawha and Ohio rivers to the southern markets. The Chesapeake and Ohio Railway Company shipped during the first five months of 1882 of coke and coal 380,000 tons, long measure, of which 40,000 tons were coke. A large portion of this shipment was east. The shipments by river in 1873 were about 160,000 tons, and in 1880 about 480,000. The Kanawha coal comes in direct competition with the coal from Pittsburgh, which has controlled and supplied the market of the Ohio and Mississippi for nearly half a century. It is, however, only a question of time when this supply will be superseded by West Virginia coal, which has been shown to be equally good, the advantage of transportation being, moreover, greatly in its favour. At Connelton, a thrifty village twenty-six miles above Charleston, good cannel coal is found, and is used extensively in the manufacture of gas. The narrow valley is studded with villages engaged in coal mining, and a dense population may be expected at no distant time.

The mining of iron ore is conducted on an equally extensive scale. A company has recently been organised under the laws of the State, with a paid-up capital of $1,000,000, called the Black Band Iron and Coal Company, for the purpose of developing the immense deposits of coal and iron ore on Davis's Creek, an affluent of the Kanawha entering that stream from the west about four miles below the city of Charleston. The company owns some 4000 acres of land, well timbered, and the whole tract is underlaid with both coking and splint coals of superior quality. In the upper parts of the ridge are extensive beds of iron oxides of the character of the well-known black ores, which have been the basis of the Hanging Rock (Ohio) industry for half a century, and they seem to be as well developed on this property as in the Hanging Rock region, where they have been used for many years in the making of car-wheel iron. They contain in the raw state about 40 per cent. of metallic iron, but the great value of this property is believed to lie in its remarkable deposits of black band iron ore. A large force of miners now at work has demonstrated that at least 2000 acres are underlaid with a deposit of this ore from 3 to 6 feet thick, and yielding, when roasted, 65 per cent. of metallic iron. The ore, as taken from the mine, contains sufficient carboniferous matter to roast it.

The company are now building the necessary furnaces for smelting the ores.

Coal in Virginia.—Mr. Owen Riordan, communicates to the *Virginias* (Staunton), some particulars relating to the Upper Potomac and Blackwater coal region. He commenced operations on the beds of this coalfield in June 1881, and opened eight veins, the thickest 9 feet, and the smallest 4 feet, measuring in the aggregate 50 feet of coal. Further operations were resumed in May of that year, another vein 10 feet thick being opened. The measures, commencing at the bottom, consisted of 1 foot 1 inch of coal, then 3 inches of broken slate, and then 8 feet 8 inches of coal. This is the only vein in that region containing slate. Two other veins, 4 and 6 feet thick respectively, were opened at a later date. Mr. Riordan says that he has now fairly proven that the Potomac River rises out of two coal veins on the eastern slope of Backbone Mountain. The coal field formerly known as the "Holy" tract, and the "Hall" and "Evans" tracts, is situated in the counties of Grant and Tucker, and is bounded on the west by the Backbone Mountain, on the east by the Alleghany Mountain, on the north by the Potomac River, and on the south by Red Creek and Dry Fork of Cheat River. It is 25 miles long, and has a superficial area of 625 square miles. Sixty-six openings have been put in this field, some on the Backbone, some on the Alleghany Mountain, and some on the Potomac River on the north, and on Red River on the south. The thickness of the vein varies from 4 inches to 11 feet 2 inches.

Recent Progress of Coal-Mining in the United States.—Mr. R. P. Rothwell (*Presidential Address to the American Institute of Mining Engineers*, August 1882) states that ten or fifteen years ago an output of from three to four hundred tons a day of ten working hours was considered good work for either a shaft or a "breaker" in the United States. Now there are collieries where 1500 and 2000 tons of merchantable coal are raised from a single shaft, broken, sized, and cleaned in a single breaker in ten hours. This is equivalent to from 200 to 250 tons an hour as the output of a shaft raising one car at a time. Some idea of the speed with which work is performed at one of these collieries, may be gained from the fact that the time occupied in taking the loaded car, carrying from two to three tons of coal off the cage, and putting the light car on, is less than six seconds in regular work; or the time from the moment the cage shows itself coming up the shaft, until it disappears going down, is, almost as uniformly as the beat of a pendulum, about seven seconds.

The work of breaking, sizing, and cleaning anthracite for market is done for about seven cents. a ton, all handling included. In no other portion of the world are the mechanical appliances for mining and preparing coal as perfect as in Pennsylvania; yet even there, many improvements have still to be made. The waste in mining and in the preparation of anthracite is fully 60 per cent. of the coal in the bed, and but little has been done to lessen this loss by the adoption of any less watchful system of mining than that in use since the mines were first opened. No doubt the introduction of the electric light will make it possible to work coal-breakers and mines both night and day, and thereby considerably reduce the amount of capital invested for a given output.

Iron Ore in Iowa.—The *Iron Age* (August 31, 1882), states, that several analyses of the ore of the iron mountains of Iowa have been made, none of them running less than 50 per cent. of iron. A full analysis is as follows:—

Sesquioxide of iron	52·571
Sesquioxide of manganese	8·054
Sesquioxide of cobalt	·230
Alumina	1·777
Lime	1·090
Magnesia	·374
Sulphuric acid	·047
Phosphoric acid	4·092
Water and organic matter	13·134
Silicious matter	18·631
Total	100·000

The deposits are distributed over 333 acres, the depth to which they extend, however, being yet unknown. It is said that several owners of land in that part of the country recently drilled a well 93 feet deep, going through 78 feet of iron ore, beginning near the surface. The quality of the ore increased in richness and value as greater depths were reached, until finally the limit was arrived at. The location of the point where this boring was made has induced the conclusion that the main deposit of the ore is perhaps hundreds of feet in depth.

Utilisation of Coal Slack.—(*Iron Age*, August 24, 1882).—A series of interesting experiments were recently made in Cincinnati with the view of testing an English process for the utilisation of slack or small coal. The experiments were made under the supervision of the inventor, W. H. Cory, of Cardiff, Wales, where the process is said to have been in successful operation since 1873. The process consists in mixing the slack or dust coal with fireclay and silicate of soda (for bituminous coal, 2 per cent. of clay and 3 per cent. of silicate), and subjecting the block to a pressure of a ton to the square inch of the block surface. The block thus formed is as hard as ordinary coal, and has all its angles rounded to prevent chipping. The surface is glazed by the manner in which the pressure is delivered, and the press turns out 240 tons in twenty hours. The blocks require twenty-four hours to become hard and fit for use. During that time the required chemical action takes place, the clay converting the silicate of soda into silicate of alumina, thus turning a soluble into an insoluble, or, in other words, vitrifying the block and causing it to be weather-proof. The tests made on the above-mentioned occasion, though lacking fulness in several particulars, are said to have been attended with satisfactory results.

The Chester Iron Ore Calcining Kiln.—The *Engineering and Mining Journal* states, that the Chester furnace of W. J. Taylor & Co. is now making about 250 tons per week of superior forge iron, mostly from the sulphury ores of Chester and Hacklebarney. This result is attributed to the excellent manner in which the ore is roasted in the Taylor gas-kiln, which is calcining regularly about 280 tons per week of hard blue ore, containing from 2½ to 3 per cent. of sulphur. The firm is building a new kiln at the furnace, the one in use being at the Hedges mine. It is understood that the new kiln will roast from 300 to 350 tons per week at a cost of not over fifty cents per ton.

Phosphorus in Charcoal.—The *Engineering and Mining Journal* (October 14, 1882), calls attention to the fact that Swedish engineers have noticed that the quantity of phosphorus in the pig manufactured with charcoal is larger than that in the ore and fluxes, even assuming that all of it had gone into the pig. Jansen found that, when he melted ores in crucibles, the metal obtained ran lower in phosphorus than the pig obtained from the same ores. Sarnström, in 1881, made some analyses of charcoal, the results of which seem to lead to the conclusion that the excess is due to that fuel. Two general samples were taken, No. 1 containing 6·8 per cent. of water, and No. 2, 5·0 per cent. Of both, four pounds of undried material were burned, yielding 1·02 and 0·83 per cent. of ash respectively. The former contained 1·64 and the latter 0·65 per cent. of phosphorus, so that charcoal No. 1 had 0·0167, and No. 2, 0·0054 per cent. of phosphorus; and assuming that the quantity of fuel used is about equal to the weight of pig produced, it will be seen that the charcoal carries about the above-named quantities of phosphorus into the cinder.

Charcoal Retorts.—Mr. Birkinbine (*Proceedings of the American Institute of Mechanical Engineers*, August 1882) states that the Baltimore Iron Company have sixteen horizontal retorts, the Port Leyden Iron Company have twenty-four Mathiew retorts, and a number of American ironworks now have or are erecting the latter. The Mathiew retort has met with most favour, and at present is being more rapidly adopted than others, because of the form and setting, and on account of the inventor making the quality of his charcoal the first claim and the quantity of the acetates collected a secondary consideration. The forms of retorts in use in this country are generally iron cylinders, either set horizontally in nests over fire-places or vertically with flues surrounding them. Departures from this plan are the Coloma, Mich., retorts, a semi-cylindrical iron bottom covered by a firebrick arch, thus forming a complete cylinder, and the Messan still, in which the carbonisation is carried on by the use of superheated steam; this, however, is principally employed with resinous woods. The Baltimore Iron Company report, as the average yield of the horizontal retorts, fifty bushels per cord. The Port Leyden Iron Company have been obtaining sixty-six bushels per cord. Part of this difference may be accounted for by the age and character of the wood used, but it is probable that a less uniform carbonisation in the horizontal cylinders is obtained than in the Mathiew retorts.

These latter are made of nearly crescent shape, to give a practically uniform thickness of wood, and are set inclined over fire-places. This method of setting is advantageous on account of the convenience of filling and discharging, and in permitting any condensed acid to drain from the retorts when cold, thus preserving the life of the retorts. It is claimed that while in operation there is little danger of the iron in the retorts being attacked by acetic acid, because the heat maintained is sufficient for volatilisation. Some two hundred of the Mathiew retorts are in place or in process of erection at various works located in different sections of the country. They are constructed of a bottom plate of half-inch wrought iron, which is protected by an arch of fire-brick. The upper portion is formed of one-eighth-inch wrought iron, connected to the bottom by angle irons. A suitable cast iron head with removable door is placed on either end, and a nozzle for conveying the vapours from the retort is secured to it. Each retort is about fourteen feet long. The capacity is one cord of wood, ordinarily cut sixteen inches long. With air-dried wood, as commonly used, the retorts require about sixteen hours for carbonisation.

The following table shows the proportion of volatile gases which are produced in making charcoal at different temperatures, and indicates how much of the contents of the wood may be lost, even at the ordinary temperatures of carbonisation :—

Temperature, Degrees at which Carbonisation was effected.			Products of the Decomposition of 100 parts by weight of Wood by Carbonisation at different Temperatures.				
			Composition of the Solid Matter or Charcoal.			Composition of the Matter volatilised.	
			Carbon.	Gaseous Elements (H.O.N.)	Ash.	Carbon.	Gaseous Elements (H.O.N.)
	Centigrade.	Fahrenheit.	Per cent.	Per cent.	Per cent.	Per cent,	Per cent.
I.	. . 150°	302°	47·51	52·41	0·08	...	...
II.	. . 200°	392°	39·95	36·97	0·18	7·56	15·34
III.	. . 270°	518°	26·17	10·65	0·32	21·34	41·52
IV.	. . 350°	662°	22·73	6·75	8·18	24·78	45·56
V.	. . 432°	810°	15·40	3·25	0·22	32·11	49·02
VI.	. . 1023°	1873°	15·37	3·12	0·26	32·14	49·11
VII.	. . 1100°	2012°	15·32	2·86	0·22	32·19	49·41
VIII.	. . 1250°	2282°	15·81	1·91	0·22	31·70	50·36
IX.	. . 1300°	2372°	15·86	1·40	0·20	31·65	50·89
X.	. . 1500°	2732°	16·37	0·83	0·11	31·14	51·55
XI.	Beyond 1500°	Melting pt. platinum.	14·48	0·23	0·29	33·03	51·97

II.—*BLAST FURNACE PRACTICE.*

Good Blast Furnace Work.—The *Iron Age* of August 31 states that the Martel furnace, which was blown in just a year previously, had in 285 working days made 11,283 tons of pig metal, with an average of 87 bushels of charcoal to the ton of iron made, commencing with 99 bushels at the start, and consuming an average of 75 bushels in the last few weeks. This is regarded as equal to the best results recently obtained in furnace working. The stack is the largest on the Upper

Peninsula—10½ feet diameter at boshes—and is described as the best equipped in the whole West.

The Iron Industry on the Pacific Coast.—The works of the Oswego Iron Company at Oswego, on the bank of the Willimette River, seven miles south of Portland, are connected with iron mines about 2½ miles distant from the furnaces, communication being established by a narrow-gauge railroad. The vein of ore can be traced for about 7000 feet, and has been opened by several inclines, one of which is 580 feet deep. The price of the ore is said to be about 75 cents. per ton at the mines. Analyses of samples of the ore have given the following results :—

	Per cent.
Silica	12·920
Peroxide of iron	64·001
Alumina	1·692
Protoxide of manganese	2·490
Lime	1·170
Magnesia	·445
Iron disulphide	·635
Carbonic acid	·210
Phosphoric acid	·278
Carbonaceous matter	.705
Water	18·985

The ore thus contains: metallic iron, 46·137; sulphur, 0·228; phosphorus, 0·548. With a properly constructed furnace of modern design it is estimated that a ton of pig iron, at the price of materials ruling at Midsummer 1882, would cost about $13, the different items being as follows :—

2½ tons of ore at $0·75	$1·87
½ ton of limestone at $5·40	2·70
100 bushels of charcoal at $0·60	6·00
Labour and repairs	2·56
Total	$13·07

The results of analyses of the pig iron produced are given in the annexed table:—

Constituents.	Chemist.					
	Drown.	Moore.	Blair.	Blair.	Grooch.	Mean.
Graphite	3·30	3·154	...	...	...	3·22
Combined carbon .	0·33	0·035	...	...	...	0·34
Silicon	2·52	...	1·592	0·779	2·52	1·99
Phosphorus . . .	1·35	1·32	1·176	1·270	1·106	1·244
Sulphur	0·012	0·013	...	...	...	0·013
Manganese . . .	1·490	1·419	...	...	...	1·450
Combined silicon . .	...	2·465	...	...	...	...
Slag	...	0 078	...	...	...	...

A calculation based on the population of the United States and the consumption of pig iron per head last year, is held to indicate that there is at present on the Pacific Coast a demand for at least 115,000 tons of iron of all kinds per annum. There are now three furnaces in operation, yielding together a daily output of 44 tons, or 15,000 tons per year, this being about one-eighth of the actual demand. A rolling mill in San Francisco turns out about 8000 tons of rails and bars yearly, made from scrap collected from different parts of the country. The works of the Colorado Iron and Coal Company, the only other works of importance in this territory, are also remote from those of the Oregon Company. The latter own 22,000 acres of timber land, 10,000 of which are in the immediate vicinity of the works, and it is estimated that this tract of land will yield an ample supply of charcoal for about 35 years.

Petroleum as a Blast Furnace Fuel.—The *Journal of the United States Association of Charcoal Workers* states that E. W. Shippen, of Meadville, Pa., has recently made some interesting experiments with petroleum as a blast-furnace fuel. He built a stack 35 ft. high, 3 ft. across the hearth, and 5ft. bosh, and fired it until it was perfectly dry. He filled it with wood 16 in. long, and kept this burning until the stack was perfectly hot before charging with oil. He then charged one barrow, containing 17 cubic ft. of wood which had been housed two years, with 200 pounds of bog ore of 42 per cent. of iron, 50 pounds of brown hematite ore and 38 pounds of limestone, and afterwards with 150 pounds of ore and a proportionate quantity of limestone. When the coals were white-hot, which was determined through a piece of isinglass in an elbow of the air pipe, he injected petroleum, which was brought from a tank 40 ft. above the tuyeres by means of a ½-inch pipe passing through the elbow of the air pipe to within 2 or 3 ins. of the mouth of the tuyere. Upon the end of the ½-inch oil pipe was a nozzle ⅛ inch in diameter. Near the elbow of the air pipe and the tuyere was a double kettle, used for boiling glue, making varnish, &c., by steam, and capable of holding 20 gallons. The oil was passed through the steam space between these two kettles on its way to the tuyeres, and the interior kettle was filled with water, which was heated by introducing steam from a boiler by means of a pipe that reached to the bottom of the vessel. The oil was in this way heated to a considerable extent before it was turned into the pipe on its way to the furnace. When the hot oil was forced into the furnace it entered in the form of spray, at a pressure of about 16 or 17 pounds to the inch, and when it struck the white-hot charcoal inside, the latter was immediately turned black, as though cold water had been thrown upon it. Mr. Shippen tried the experiment with the smallest perceptible amount of oil up to the full amount that the nozzle would pass, and in each trial the same effect was produced, and the gas which came out at the tunnel with a bright flame when the wood was burning was turned into a dark-red flame with a black smoke. This change was brought about immediately upon turning on the oil, without regard to the quantity of the latter. The consequence was that the ore could be melted, but could not be raised to a sufficiently high temperature to separate the iron from the slag. An iron air cylinder or blast engine of 5½ cubic ft. capacity was used in the experiments. This was worked first at a speed of 80 strokes per minute, then at 120 strokes, and afterwards at 40 strokes, with various intermediate speeds, but the same result was obtained in each case. Mr. Shippen has had considerable experience with blast furnaces, and his opinion, as well as that of several other gentlemen who had been in the foundry business for some time, was to the effect that oil used in this manner would soon chill up the furnace.

The Didier Tuyere.—The Didier double-wrought copper tuyere, which has recently been introduced, is said to obviate some difficulties pertaining to tuyeres at present in use. It consists of a tuyere or blast pipe, covered externally with two water jackets, one of which surrounds and extends over the end of the other, each having a separate system of water supply and discharge. The inner blast pipe is of the usual size, and is surrounded by an outer shell of the same or nearly the same length, the two being connected at the nozzle by a flange. The space thus enclosed between the iron pipe and the outer shell is divided by an inner shell into two separate water-chambers, the inner shell being connected to the blast pipe by a flange in substantially the same manner as that before-mentioned, at a distance equal to the radial distance between the two shells. The outer chamber thus surrounds and covers both the inner chambers and the blast pipe, and also extends over and covers the front end of the inner chamber. The rear ends of the two chambers are closed by a metallic ring, which is secured in place between the pipe and the shells, by water-tight connections, either in the course of manufacture, as in casting, or subsequently when putting into place. These rings are perforated with holes, four in each, for the separate supply and discharge of water from each chamber.

The inner water-chamber is thus protected on both its outer cylindrical surfaces, and on its closed end from the heat of the furnace by the outer chamber. The latter is protected over the greater part of its surface from the heat of the blast, one function of the inner chamber being to cool the water in the outer chamber, as the latter when in use is exposed to the greater heat. The inner chamber thus serves a double purpose, and by means of the mutual protection of the two chambers the tuyere is said to last twice as long as an ordinary tuyere having only a single water-chamber. It is usually found disadvantageous to shut off the blast at a particular time, and in the improved tuyere the water supply for the outer chamber may be shut off in case the outer shell should be destroyed. The inner chamber can be still supplied with water, thus permitting the successful use of the tuyere until a convenient opportunity would arrive for the necessary repairs, or for the insertion of a new tuyere.

Charcoal as a Fuel for Metallurgical Processes.—In a paper on this subject, read before the American Institute of Mining Engineers,* J. Birkinbine, Secretary of the United States Association of Charcoal Ironworkers, states that charcoal at present produces 18 per cent. of all the pig iron made in that country. During 1881, 638,838 net tons of pig iron, and 84,606 net tons of blooms and billets, a total of 723,444 net tons were made with this fuel, consuming about 1,000,000 net tons of it. Never in the history of the iron trade have so great quantities, both of pig iron and blooms, been made with charcoal as fuel, and it is probable that 1882 will considerably exceed the product of 1881. If to the amount of this fuel used at iron works could be added, that consumed in the various smelting works of the silver and other metallurgical industries, the total annual consumption of charcoal in the United States would be found to approximate 2,000,000 net tons annually. The world's yearly production of charcoal pig iron approximates 2,000,000 gross tons.

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* Danver (Colorado) Meeting, August 1882.

The Cost of Producing Charcoal Pig Iron.—Before the Tariff Commission, now sitting, to inquire into the subject of the duties on iron and steel, George W. Moore, of Detroit, gave evidence on behalf of the charcoal iron interest of Michigan. He stated that near the close of 1881, he addressed to a number of charcoal furnaces a blank form, asking them to report to him the rates of wages paid to the different classes of labour and the actual cost for labour in the manufacture of a ton of charcoal pig iron from the ore in the mine to the nearest general market. He received 19 reports from furnaces and mines located in New York, Michigan, Georgia, Maine, Alabama, Tennessee, Pennsylvania, and Virginia. These returns showed the following as the average rates of wages for the different classes of labour:—

	Per day.		Per day.
Miners' wages	$1·79	Charcoal burners	$1·83
Labourers	1·45	Founders	2·80
Teamsters	1·60	Assistants or keepers	1·68
Choppers	1·28		

The following was given as a statement of the average cost of labour alone in the manufacture of a ton of charcoal pig iron in the United States, as gathered from the 19 reports above referred to:—

Labour in ore, per ton of metal	$3·30
Labour in limestone, per ton of metal	·35
Labour in transportation and handling at the furnace	1·60
Labour for charcoal	7·40
Labour in smelting	2·33
Labour in transportation and handling of pig iron to the nearest market	1·70
	$16·68

This does not include the cost of management, superintendence, or clerical labour, or labour in repairs, but simply manual labour; and $2 per ton additional would, in Mr. Moore's opinion, be a moderate estimate of this cost.

III.—*MANUFACTURE AND PROPERTIES OF STEEL, &c.*

The Garrett Wire Mill.—Mr. B. C. Lauth, of Philadelphia (*Bulletin of the American Iron and Steel Association*) gives an account of the Garrett Wire Mill, at Cleveland, Ohio. The mill consists of one train of three sets of 18-inch rolls, one intermediate set of 12-inch rolls, and two 9-inch trains, with four sets of rolls to each train. The trains are all placed parallel to each other, and the billets used at present weigh 100 pounds, but they can roll 140 pounds without any trouble. There are three engines—No. 1 drives the 18-inch trains, and it is intended to put a 24-inch blooming-mill on the other side of this engine to roll down a 10-inch ingot into a 4-inch billet. This will be cut into 100-pound billets, which will be put into the furnace hot, and from there will go to the rod-mill as required, the ultimate intention being to finish 10-inch steel ingots direct from the converter into No. 4 or 6 wire rods, without allowing the steel to get cold. No. 1 engine is 40-in. by 42-in. and is direct acting. No. 2 engine is 36-in. by 42-in., and drives the one set of 12-inch and four sets of 9-inch rolls. The 12-inch rolls are driven from a counter-shaft with a 24-inch belt. The four sets of 9-inch rolls are driven by a 36-inch belt. The No. 3 engine is 36-in. by 42-in., and drives the four last sets of 9-inch rolls with a 36-inch belt. Mr. Garrett has arranged two reels to take his rods as they are finished, and in this way, if anything should occur to one reel, the other is always ready for work. The reels are driven from a shaft overhead, each reel having a friction-clutch, so that it can be easily controlled.

Plate-Trains.—The *Iron Age* states that some improvements have recently been introduced in American roughing rolls, including an arrangement of gear-wheels, which manipulate the housing-screws, and raise and depress the top roll, thereby dispensing with screws worked by hand. The primitive "heave-up" with his hook has also been superseded by steam or hydraulic lifting tables, which raise the pile or bloom to a point that is level with the periphery of the top across which it is passed. With three furnaces, a modern American plate-train will deal with about thirty tons per day.

Steel Casting.—(*Iron Age*, Sept. 21st, 1882.)—A new process, invented by Mr. George Cowing, of Cleveland, Ohio, and now owned by the Cowing Steel Casting Company of that place, is said to be attracting a good deal of attention among steel manufacturers and others interested in the production of sound, soft, and accurate steel castings. Briefly described, the process is one of making the mould of pure silica, held together by a slight admixture of flour and glue-water, merely enough being used to give adhesion to the material. An incidental advantage of the new method of making moulds over that employed in England, is the fact that the mould, after being poured, loses its adhesion about as completely as a green-sand mould, and of course offers no resistance to the shrinkage of the metal, while the Lowood mould is very hard, and is liable to induce fractures while the metal is in process of cooling. In making the new moulds a finely-ground quartz is used, mixed with glue and flour. Such a mould would be too porous if no facing was used, the melted steel being very fluid, and penetrating even the spaces left between the particles of sand forming the mould. This consists of silica or quartz, ground to an impalpable powder, and applied in the usual way. When this is thoroughly slacked down, the surface is dense enough to resist the passage of metal, but will allow the free escape of gas. With these moulds it is said that any grade of steel can be cast with ease, and not only without alteration in its chemical composition, but with perfect freedom from blowholes or imperfections of any kind. Mr. Cowing states that he has made castings containing only ·07 per cent. carbon, a percentage so low as to bring the metal more properly within the grade of wrought iron than steel. Castings of this grade, when taken from the mould, are said to bend nearly double without any annealing.

The Relations of Manganese and Carbon in Steel.—M. A. Pourcel, in a paper read before the American Institute of Mining Engineers,* states that the deterioration of rails from atmospheric causes, which may be considered as equivalent to chemical action, is due to their physical condition rather than to the chemical composition of the ingot from which the rail is made. A porous ingot full of blow-holes will produce a rail on which, after a few months' service, the surface exposed to wear will be covered with numberless little rays or streaks which form convenient points of attack for the atmospheric agents. A rail of this description, if laid in a damp tunnel, will become useless in a short time. It would probably be rendered useless somewhat more rapidly if it contained a high percentage of manganese, but in no case would the presence of that element be the principal cause of the effect produced. If two rails made from two ingots perfectly sound and free from blow-holes are compared with each other as regards mechanical wear, M. Pourcel's opinion is that moderately hard rail will resist wear much more effectually than the softer one. The maximum of rigidity, combining resistance to bending with great power to resist shocks, has been reached in rails of the following composition :—

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* Danver Meeting, August 1882.

Carbon	0·50	to	0·4
Manganese	0·90	,,	1·10
Phosphorus	0·08	,,	0·10
Sulphur	—		0·05
Silicon	—		0·02

These rails made from perfectly sound ingots and laid on one of the busiest portions of a great network of French railways, have not given occasion for a single rejection after a three years' trial, and the wear which has been observed has been insignificant. Other rails made from ingots equally sound, and differing from the preceding one only in having a smaller amount (from five to seven-tenths of one per cent.) of manganese, have been rejected after the regular three years' test, and it has been specially remarked that there has always been a notable wear of the top of the rail. M. Pourcel states, moreover, that the rails which have best resisted the rude tests, percussion and bending, demanded by the Russian railways, contain about three-tenths of one per cent. of carbon, and from one and one-tenth to one and two-tenths per cent. of manganese. The manganese, without sensibly diminishing the elongation of the steel, increases its tenacity and rigidity, as well as its power of resisting shocks, imparting to the steel the quality of hardness without brittleness.

In August 1881, M. Pourcel was in possession of quite a large number of old steel rails made at different steel works in Germany, and taken from the railways of Alsace and Lorraine, which had been worn out quite rapidly and were in very poor condition. The oldest of them bore the date 1874 and the mark "Bochum." The most recent came from the steel works of "G. H. Hütte" and were dated 1879. These rails, in their chemical composition, correspond for the greater part with Dr. Dudley's formulæ, those at least which did not have any excess of phosphorus or silicon, but their resistance to wear has not confirmed Dr. Dudley's opinion. M. Pourcel has also been able to submit one rail from the Phœnix Steelworks, one from the Osnabrück Steelworks, and another made by Hoesch, to the test of a blow. The first rail showed the greatest power of resistance, but the metal was soft and the shape of the rail was changed considerably. The Hoesch rail changed its shape still more easily, besides being brittle. It broke under the blow of a weight of three hundred kg. falling through three and a-half m., the anvil weighing twelve tons. The Phœnix rail resisted the shock of the same weight falling through four and a-half m. The Osnabrück rail, like that of Hoesch, was brittle, but its form was changed less easily. Like Dr. Dudley, M. Pourcel has come to the conclusion that elements like phosphorus, silicon, and sulphur, must be reduced to an absolute minimum in a good rail, and he adds that he would insist especially on the elimination of the phosphorus and the silicon, and less on that of the sulphur. Manganese, in his opinion, is not injurious either to the rolling or to the use of the rail, and he gives preference to a metal containing about one per cent. of manganese, this metal being excellent for rolling and yielding a rail of superior wearing qualities.

The annexed table shows the partial composition of different rails :—

Description of Rail.	M.	C.	Si.	S.	P.
Phœnix . .	0·373	0·490	0·093	0·034	0·102
Krupp . .	0·373	0·323	0·139	1·036	0·146
Bochum . .	0·240	0·200	0·116	0·026	0·067
Union Dortmund	0·240	0·284	0·046	0·039	0·239
G. H. Hütte .	0·480	0·382	0·149	0·039	0·080
Osnabrück .	0·586	0·170	0·466	0·045	0·174
Hoesch . .	0·453	0·330	0·291	0·038	0·119

Tests of Bessemer Steel.—The Pittsburg Steel Casting Company have recently made a series of tests and carbon determinations of their refined Bessemer steel, in order to show the uniformity which may be attained in its manufacture. The results of the several tests were as follows :—

No. of Blow.	Elastic Limit.	Elongation in one inch fracture, per cent.	Tensile Strength.
700	Not taken.	52	61,280
701	32,272	50	63,448
702	34,669	62½	63,200
703	33,333	50	64,800

The steel was rolled into boiler plate, and was flanged and "crimped" without showing the least inclination to break. The carbon determination of 73 separate blows, where the carbon was not to exceed 0·10, and to be as near that as possible, gave the following results:—

54 blows below	0·10
14 blows below	0·10
1 blow below	0·11
2 blows below	0·12
1 blow below	0·13
1 blow below	0·14

In spring steel the same uniformity was secured. In 65 blows of this steel, where the carbon aimed at was 0.66, the following results were obtained:—

5 blows	0·63
10 blows	0·65
16 blows	0·66
11 blows	6·67
15 blows	0·68
8 blows	0·69

The average being 0·666.

The Mechanical Properties of Steel.—Mr. William Metcalf, in a paper read before the Engineers' Society of Pennsylvania, states the following conclusions:—

1. That a good soft heat is safe to use, if the metal be immediately and thoroughly worked, for good steel will endure more pounding than iron.

2. If steel be left long in the fire, it will lose its steely nature and grain, and partake of the nature of cast-iron. Steel should never be kept hot longer than is necessary for the work to be done.

3. Steel is entirely mercurial under the action of heat, and there must, of necessity, be an injurious internal strain created whenever two or more parts of the same piece are subjected to different temperatures.

4. It follows that when steel has been subjected to heat not absolutely uniform over the whole mass, careful annealing should be resorted to.

5. The change of volume due to a high degree of heat increases directly and rapidly with the quantity of carbon present, therefore high steel is more liable to dangerous internal strains than low steel, and great care should be exercised in the use of high steel.

6. Hot steel should always be put in a perfectly dry place of even temperature while cooling. A wet place in the floor might be sufficient to cause serious injury.

7. Over-heated steel can be restored by first bringing it to a red heat and allowing it to cool slowly. For "burned" steel, which is oxydised steel, there is only one way of restoration, and that is through the knobbling fire of the blast furnace.

8. If carried too far, annealing does great harm, and is one of the commonest modes of destruction which the steelmaker meets in his daily troubles.

The Cost of Making Steel Rails.—The *Boston Herald* is responsible for the following estimate of cost of manufacturing Bessemer steel rails, the figures, it is said, having been got up independently by the superintendents of three mills, whose estimates were very nearly alike:—

Cost of a Ton of Steel Rails.

22 cwt. pig iron, at $27 per ton	$29·70
1½ cwt. spiegel, at $38 per ton	2·85
3 cwt. coke, at $3·50 per ton	·52
Sand, fireclay, &c.	·75
Coal for stoves, steam service, &c.	·25
Stores	·15
Wages	2·00
Management, clerking, &c.	·20
Cost of ingots per ton	$36·42
20½ cwt. of ingots, at $36·42 per ton	37·33
8 cwt. of coal (for reheating) at $2 per ton	·80
Labour	1·25
Stores	·10
Cost of blooms per ton	$39·48
22 cwt. of blooms, at 39·48 per ton	$43·43
8 cwt. of coal (for reheating) at $2 per ton	·80
Wages for heating, rolling, sawing, punching, &c.	2·50
Stores	·15
Cost of steel rails per ton	$46·88

In the above estimate, pig iron is said to be started with at $27 per ton, the highest market price, when, as a matter of fact, the iron could be had at a much cheaper rate—say $20 per ton—almost anywhere in the neighbourhood of iron furnaces.

The Danks Furnace in the United States.—At the works of the Cincinnati Rolling Mill Company, there is now a plant of seven Danks furnaces in regular operation. Each furnace makes seven heats a day, single turn, the charge being 650 lbs. of pig iron, and the product about

670 lbs., the excess being gained from the ore and scale used. The product is made into a ball by the revolving of the furnace, and is afterwards worked into a solid cylindrical ball, or bloom, in a Winslow squeezer, fitted with a steam ram for compressing the ends. This squeezed ball is at once, without re-heating, taken to a three-high 21-inch train and rolled into muck bar 7½ inches by 1 inch, which is sheared hot into lengths for piling for tank plate.

Part of the product is made into boiler-plate, for which the operation is somewhat different. The squeezed blooms, instead of being rolled at once, are taken to a hammer and hammered to about 7 inches square. They are then re-heated and rolled to a bar of about 3½ inches by 1 inch, and piled crosswise and lengthwise in alternate layers, and heated and hammered again into a slab, which is heated and rolled into the boiler-plate. The plates made by this process pass the Government inspection for marine boiler-plate, being stamped 50,000 lbs. to 55,000 lbs. tensile strength.

The revolving puddling furnace is practically the same as that in use at Graff, Bennett, & Co.'s works. The comparatively small size of the bloom (being 650 lbs., while that of Graff, Bennett, & Co. is 900 lbs. or more) is due to the lack of facilities for handling and finishing at the Cincinnati mill, the three-high 21-inch train not being so good a machine for treating the squeezed bloom as is the reversing two-high universal mill in use at Pittsburg. The Messrs. Danks say that there is no reason why their furnace should not make a bloom of 2000 lbs., and that with a strong universal mill this could easily be rolled into muck bar one inch or less in thickness. The *Bulletin* points out that, if their furnace can uniformly and economically make blooms of such a size, there would be a vast saving in labour and in scrap over the old-fashioned process of dividing the 480 lbs. products of a furnace into three balls, and handling each one separately.

The labour employed at Cincinnati consists of one skilled puddler and one helper to each furnace, with another helper or labourer to each two furnaces. The labour required if the charges were doubled would be but little if any greater than this. As for the amount of fuel consumed, it cannot be said that the Danks furnace has at present any advantage over the ordinary furnace, except that due to the fact that it makes seven heats a day to the five or six of the old style. A perfected Danks plant should have a cupola or other furnace for melting the pig iron before it is put into the puddling furnace.

B.—STATISTICS, &c.

Production and Consumption of Steel Rails.—(*Engineering and Mining Journal*, Oct. 1882).—The mileage of new railways constructed in the United States during the first nine months of 1882 was 7285 miles, against 4772 miles in the corresponding period of 1881. The probable total mileage of new track laid in 1882 will be 12,000 miles, which will represent a probable consumption of 1,375,000 tons of rails, against an actual consumption of 1,067,000 tons on the same account for 1881. The quantity of rails required for renewals in 1882 is estimated at 900,000 tons, against 1,163,422 tons in 1881. The renewals are estimated only at 900,000 tons, because the requirements for that purpose during the last four years of railroad prosperity have been so heavy that probably less is doing in that direction. This makes a total probable consumption of 2,275,000 tons of iron and steel rails. Last year, the United States made 1,330,302 net tons of steel rails, including 77,173 tons rolled from imported blooms, and imported 249,309 tons, a total of 1,579,611 tons. In 1881 the United States Bessemer works had a capacity of 1,750,000 tons of ingots. Now their capacity is 2,250,000 tons of ingots. Deducting rails from imported blooms, and assuming that the proportion of ingots to rails has remained the same, and allowing 25,000 for the quantity of rails rolled in this year from imported blooms—a business which has declined—a probable production of about 1,700,000 tons is reached. To this must be added imports this year aggregating 106,000 tons up to August 1. Should it happen that at present prices no more steel rails will be sent to America, there is here a total supply of 1,885,000 tons, leaving only 450,000 tons to be supplied by iron. Last year, the production of iron rails was 488,581 tons, and the imports 137,013 tons, a total supply of 625,594 tons. The imports thus far are not much above 40,000 tons, and the production is not likely to go much higher than 400,000 tons.

The Number and Capacity of American Iron and Steel Works.—*The Directory to the Iron and Steelworks of the United States*, compiled by Mr. J. M. Swank, and corrected to July 25, 1882, enables a comparison to be made of the present producing capacity of these works with their condition on March 1, 1880, when the last edition of the directory was completed. On July 25, 1882, there were 686 completed blast furnaces in the country, against 697 on March 1, 1880—

an apparent decrease of 11, although 44 furnaces were in course of erection at the latter date, against 30 in July of this year. The decrease in the number of blast furnaces arises from the fact that there have been relegated to the "abandoned" list a great many furnaces which have been out of blast so long that there is now no hope of their ever being re-started. The number of furnaces, however, affords no guide to their capacity, which now stands at 8,000,000 net tons a year, against 6,500,000 tons on March 1, 1880, the great increase being, as might be expected, among the bituminous furnaces, which advanced from a capacity of 2,825,000 net tons to 4,125,000 tons.

The classification of blast furnaces in the United States according to the fuel used shows but slight changes. There are now 210 bituminous, 225 anthracite, 250 charcoal furnaces, and one built to use gas. On March 1, 1880, there were 203 bituminous, 228 anthracite, and 266 charcoal. Bituminous furnaces are increasing in number, while the others appear to be decreasing.

The rolling mills and steel works have grown from 382 in 1880 to 393, and 16 are now building, against 10 in 1880. The capacity of the rolling mills in finished iron and steel was then 5,250,000 net tons a year, while now it is 7,000,000 tons—the resources for the production of rails alone having grown from 2,150,000 net tons to 3,110,000 tons. The number of rail mills has, however, decreased, standing at 80 now, against 87 in 1880. Of these, 48 mills now make heavy rails, against 54 in 1880; and two mills were in course of erection to make heavy rails, while 2 were building in 1880.

The number of puddling furnaces now available is equivalent to 5018 single furnaces, while in 1880 the equivalent resources were 4467; of heating furnaces there are now 2598 against 2419 in 1880; of trains of rolls, 1424 now, against 1397 in 1880.

The number of nail factories has decreased, there being 66 now, with 2 building, against 73 on March 1, 1880, while there are 4030 nail machines now in use, against 4152 then. The causes of this decrease in the nail trade are various: some factories have been burnt and not rebuilt, others have been dismantled, and others have been idle so long that they are now regarded as abandoned. Notwithstanding the decrease in the number of nail factories since 1880, there has been no decrease in the production of nails.

The number of Bessemer steelworks has increased from 11 to 14, and of open-hearth steelworks from 22 to 27, while the crucible steelworks remain at 35. One Bessemer steelworks and 5 open-hearth steelworks are now being built. The completed Bessemer steelworks and the works building have a capacity of 2,250,000 net tons of ingots a year, while on March 1, 1880, the works then existing and building claimed a capacity of but 1,750,000 tons. There were then 22 converters, with 10 building; there are now 36 converters, with 2 building. The completed open-hearth steelworks on March 1, 1880, had 33 Siemens furnaces, and the works building were expected to add 6 more. There are now 51 completed Siemens furnaces, and 10 building. The total annual capacity of the open-hearth steelworks will be 500,000 net tons when the additions, now being made, are completed; while on March 1, 1880, the total annual capacity of completed and unfinished works was but 275,000 tons. The number of pots in the crucible steelworks has increased from 3080 to 3490, with an increase in the annual capacity of the works from 90,000 net tons to 105,000 tons.

Only 6 works are now engaged in making the other kinds of steel, against 9 on March 1, 1880; but 47 works now buy steel and roll it into merchantable shapes, against 31 then. Almost every month witnesses either the addition of a steel plant to an ironworks in some part of the country, or else the partial transformation of an ironworks to a steelworks by the adaptation of heating furnaces and rolls to the manipulation of purchased steel blooms and billets.

There are now 72 forges which make wrought iron direct from the ore in Catalan or analogous fires, against 69 on March 1, 1880, and the annual capacity is now put at 75,000 net tons, against 85,000 tons then. Of bloomeries working up scrap and pig iron there are now 52, with one building, against 59 on March 1, 1880. The annual capacity is now 70,000 net tons, against 80,000 tons then.

The following table summarises the annual capacity of production of the iron and steel works in the United States :—

Works.	Net Tons.	
	March 1, 1880.	July 25, 1882.
Blast furnaces . .	6,500,000	8,000,000
Rolling mills . . .	5,250,000	7,000,000
Bessemer steelworks .	1,750,000	2,250,000
Open-hearth steelworks .	275,000	500,000
Crucible steelworks . .	90,000	105,000
Forges using direct process	85,000	75,000
Bloomeries . . .	80,000	70,000
Total . .	14,030,000	18,000,000

AUSTRIA.

A.—METALLURGICAL TECHNOLOGY.

Gmelin's Cupola.—O. Gmelin, of Budapest, describes in *Oest. Zeitschrift für Berg- und Hütten W.* (1882, No. 41) his new cupola. It is essentially formed of a double cylinder of boiler plate, through the ring-shaped space of which water circulates. Only the lower part, viz., the well for the reception of the melted metal, consists, to a height of ·3 to ·35 metres, of fireproof material. On it rests the iron body, which receives a fireclay lining of 1½ to 2½ in. in thickness. The water enters at the bottom, and is discharged from a pipe at the upper part of the furnace. The two cylinders are kept at a proper distance by a flanged cast iron ring which loosely covers the intermediate space. A cupola on this system, of 4 metres height and ·85 metres clear diameter has been in use every week-day for more than a year at the wagon-works of Messrs. Ganz & Co., where it has given in every respect excellent results. During this period, no repairs of the iron parts have been needed, and on recently examining it, the inner iron cylinder was found to be perfectly intact. Herr Gmelin claims the following important advantages for his invention. It may be kept in continuous blast for any length of time, yielding, with the same charge, from beginning to end the same quality of metal, as no accumulation of heat can take place, and the shape remains perfectly unaltered. A very high blast pressure does not alter these conditions, consequently twice as much metal may be melted in it as in an ordinary cupola of the same size. Notwithstanding the larger amount of heat carried off by the cooling water—about 15 per cent. of the heating power of the coke against 5 per cent. absorbed by the walls of firebrick lined cupolas —the consumption of coke is very low, only about 8 per cent. being required, while 4½ to 5 tons of iron are melted per hour. This economy is due to the very regular going down of the charges, the perfect shape and the smooth surface of the inner cylinder. Very little carbonic oxide seems to escape from the throat, as may be concluded from the absence of flame, except on blowing out. There are next to no repairs required, as any parts of the lining which may break out readily replace themselves by a crust of slag. The quantity of slag formed is very small, as it is not increased by parts of the lining. Large additions of limestone or other fluxes may be made without damage to the furnace, which is claimed as an advantage when a first-class metal is required.

The Siemens-Martin Process with Additions of Ore and Charcoal.—M. Ehrenwerth of Leoben and J. Prochaska of the Gratz Steelworks have patented the use in the Siemens-Martin process of blocks composed of ore, charcoal (or coke), and pig iron, which are charged in place of scrap iron. The blocks are prepared either by filling moulds with a mixture of coarse pieces of charcoal (or coke) and ore, and filling the interstices with liquid pig iron, or by moulding bricks of a mixture of small coke (or charcoal) and ore, and casting pig iron around them. Herr Ehrenworth communicates to the *Oest. Zeitschrift für Berg- und Hütten W.* (1882, No. 42 *et seq.*) some of the results obtained in experiments which Herr Prochaska carried out at the Gratz Steelworks. Although not a decided success, they proved the feasibility of the scheme. The blocks contained from 11 to 15 per cent. of best calcined Erzberg ore and 2·8 to 1·7 per cent. charcoal, besides the pig iron. The experiments were varied in several ways, and the advantage of the mixture of carbon and ore was proved beyond doubt. From 5 to 8 per cent. more iron was so obtained from the ore than when the same quantity was used without charcoal. Combinations of ore and charcoal, not previously moulded, but thrown immediately (at a high temperature) on the bath in the Siemens furnace, were tried likewise, and gave nearly equally good results. The slag, first black by the fusion of the ore, gradually, through the reducing action of the coal, became light coloured, while a quantity of metal was contributed to the metallic bath. A great inconvenience consists in the rapid wear of all furnace linings. A good silicious lining was found to stand best. By replacing part of the compound by scrap iron, this destructive action is not more perceptible, and some of the benefits of it may still be realised.

For the comparison of the cost of the materials for the production of 100 parts of steel by the Bessemer converter, by the Siemens-Martin process with scrap, and by the Siemens-Martin process with ore and charcoal, Professor Ehrenwerth supplies the following figures:—

Bessemer Process, direct from Blast Furnace, without Spiegel.	Siemens-Martin Process.	
	With Scrap.	With Charcoal and Ore-Blocks.
112 grey pig at 60 kr. = 6·72 fl.	25 white iron at 54 kr. = 1·35 fl. 78 scrap at 6 kr. = 4·68 fl.	95 white pig iron at 54 kr. = 5·13 fl. 20 ore at 6 kr. = ·12 fl. 1·5 coal at 1·5 kr. = 0·3 fl. 2 large coal at 10 kr. = ·20 fl.
6·72 fl.	6.03 fl.	5·48 fl.

The quality of the metal, some of which was used for locomotive plates, was equal to the best Austrian Siemens-Martin steel.

Titration of Manganese by Potassium Permanganate.—A. E. Haswell of Vienna describes Volhard's process for the estimation of manganese as adapted to the analysis of steel and iron. Volhard ascertained that solutions of the protosalts of manganese are precipitated completely by potassium permanganate, in the form of peroxide, if sufficient calcium, magnesium, barium or zinc salts are present to combine with the MnO_2; in the absence of these bases, part of the MnO of the solution takes their place, and a precipitate of uncertain composition results, while less than the quantity of permanganate corresponding to the normal reaction is needed.

Volhard recommends the addition of some drops of a solution of $ZnSO_4$ to the solution of the manganese salt, and to run in gradually, at 100° C., a standard solution of permanganate till a permanent pink colouration is observed. Some time should be allowed, and the heating to 100° be repeated. The quantity of permanganate used will then give the manganese present. The standard solution is best made of such a strength that 1 cc. indicates ·002 grms. of manganese; this corresponds to a solution of 3·833 grms. permanganate in 1 litre of water. The solution to be tested should not contain more than 25 per cent. Mn.

Concentration and heat accelerate the separation of the brown precipitate. Only a moderate acidity of the solution is allowable. The solution is best acidified with nitric, acid which counteracts the influence of traces of organic matter (fibres of filter paper, &c.); H_2SO_4 retards the reaction, HCl should be absent. None of the bases usually accompanying Mn have any influence; of iron, however, only the smallest quantities, in the state of persalts, are admissible. Volhard has succeeded in finding an excellent reagent for the removal of iron in ZnO (ignited commercial zinc-white) ground finely with water. It precipitates the iron perfectly from cold solutions as hydrate, which readily settles. The separation is so perfect and easy that this method of estimating Mn will supersede all others.

To standardise the permanganate, Volhard makes use of its reaction with a solution of KI acidified with HCl. Permanganate added to this immediately liberates a quantity of I equivalent to its active oxygen, provided sufficient KI remains unacted on to keep the liberated I in solution. He proceeds as follows: 10 cc. of a solution of KI of 5 per cent., and 4 to 5 drops HCl are added to 150 to 200 cc. water; 20 cubic centimetres of the permanganate solution to be standardised are then run in while the liquid is continually stirred. The quantity of the I liberated is next determined in the usual manner by a standard solution of hyposulphite.

For the testing of iron and steel it is best to dissolve the sample in a mixture of 3 vols. of dilute H_2SO_4 of 1·13 spec. gravity and 1 vol. HNO_3 of 1·4, and to evaporate on the water-bath to dryness. If it is rich in carbon, the residue is dissolved in HCl and water, filtered, and the filtrate, after the addition of a little sulphuric acid, evaporated till fumes begin to come off, so that all traces of carbon compounds are destroyed. If the steel is low in carbon, the original solution, after evaporation to dryness, is gently heated, redissolved in HNO_3 and put into a measuring flask. After neutralisation with caustic or carbonate of soda, oxide of zinc is gradually added till the precipitated hydrate of iron settles readily, leaving a milky supernatant solution. After a few minutes' settling the solution may be filtered. Iron ores, &c. are treated in an analogous manner.

A measured portion of the filtrate, 50 or 100 cc., is now put into a flask, acidified with a drop of nitric acid and heated to 100° C. The flame is then removed and permanganate run in by drops while the flask is continually agitated. As soon as the supernatant solution shows on settling a pink colour, the flask is again heated and shaken; if the colour disappears, a few more drops of permanganate are added, till a permanent slight excess is present. If the solution was not too much acidified, a titration can be executed in fifteen minutes. Too much free acid retards the action very considerably; frequently good results were obtained without acidifying, in which case the success was probably owing to the perfect absence of organic matter. One drop of acid on 100 cubic cm. of solution is perfectly sufficient.

The following analyses show the degree of exactitude of which this method is capable. The permanganate was of such a strength that one cubic centimetre precipitated ·0015 Mn.

1. *$MnCO_3$*: ·402 grms. were dissolved in HNO_3 and neutralised with Na_2CO_3 solution, a few drops of $ZnSO_4$ were added, and the solution made up to 100 cc. After acidifying, it was found that 2 cc. of the solution required 2·5 cc. permanganate, 10 cc. required 12·5 permanganate, from which follows, for the total of the solution, ·399 $MnCO_3$ instead of ·402.

2. *Sparry Iron Ore.*—2·2133 grms. were dissolved and freed from iron as directed above and the solution made up to 500 cc.; 20 cc. of this required 2 cc. permanganate, other 20 cc. filtered, but not acidified, required 2 cc. permanganate; 100 cc. filtered and acidified required 10 cc., all these trials giving 3·38 per cent. Mn. Other 100 cc. of the filtrate were analysed gravimetrically—the zinc separated as sulphide and Mn precipitated by Br, when 3·385 per cent. Mn were found.

3. *Pig Iron.*—1·044 grms. treated as above, the solution, after precipitation of iron, made up to 500 cc., 100 cc. of this, acidified, required 4·1 cc. permanganate, corresponding to 2·94 per cent. Mn. From other 100 cc. the Mn was precipitated as sulphide, when a quantity corresponding to 2·90 Mn was obtained.

4. *Steel.*—3·0283 grms. freed from iron and made up to 500 cc.; 100 cc. required 2·1 cc. permanganate, equal to ·52 per cent. Mn. From other 100 cc. the Mn was isolated as Mn_3O_4 when ·512 per cent. Mn were obtained (*Dingler's Polytechnisches Journal*, vol. ii. pp. 35, 387).

On the Influence of the Blast Pressure in Blast Furnace Practice.—H. Schellhammer contributes to the *Oest. Zeitschrift für Berg -und Hüttenwesen* (No. 35 *et seq.*) an elaborate paper on the relation of the pressure and quantity of the blast to the consumption of fuel and the composition and temperature of the gases.

For the purpose of his valuable researches he made a careful study of the work of a newly rebuilt charcoal furnace in which 194·7 kilos. calcined ore and 15 kilos. slate (as flux) are needed for 100 kilos. of white pig iron.

The furnace was started in the customary, and, in the author's opinion, perfectly correct manner, which is as follows:—The furnace is blown in with small tuyeres and moderate pressure. Gradually the pressure is increased as long as a saving of fuel can be effected by it, and the working of the furnace remains regular. Next, larger tuyeres are put in, and the pressure is first lowered, then gradually raised, till again the limit of consumption is reached. These trials are repeated with gradually increased pressure and diameter of tuyeres till the most favourable conditions are established.

Detailed observations were made under 8 different conditions of blast supply: No. XI. representing the work of the old furnace before it was blown out, No. I. to VI. and X. the performance of the rebuilt furnace after a few weeks of regular work. The following table shows at a glance how completely, through only changing the blast pressure, all the most essential elements in the working of the furnace are modified. The differences in the composition of the gases are expressed by the proportion of the weights of CO_2 and CO, which was ascertained from an average of 4 to 10 analyses each. The temperatures of the gases are also averages of numerous careful observations.

TABLE No. 1.

Series A, Diameter of tuyeres 56 millim. (2·2 *in.*) *New Furnace.*

No.	Blast.		$\frac{CO_2}{CO}$ in Gases.	Temperature of Gas.	Charcoal per 100 White Pig.	Make in 24 Hours.
	Pressure. Millim.	Temperature.				
					Kilos.	Tons.
I.	90	150° C.	·643	300° C.	92·	19·7
II.	135	150° C.	·995	320° C.	79·	23·0
III.	165	150° C.	1·038	330° C.	78·	26·6
IV.	190	150° C.	1·268	350° C.	73·	30·0
V.	200	150° C.	1·373	370° C.	72·14	34·0
VI.	210	150° C.	1·518	445° C.	71·82	35·0
Series B. Diameter of tuyeres 66 millim. New Furnace.						
					Kilos.	Tons.
X.	190	150° C.	1·850	450° C.	69·	36·0
Series C. Diameter of tuyeres 70 millim. Old Furnace.						
					Kilos.	Tons.
XI.	195	150° C.	·880	320 C.	77·	30·0

By calculation from these data Herr Schellhammer derives the quantities of blast and gases, and the quantities of CO and CO_2 as formed by different reactions and in the different regions of the furnace. He lays particular stress on the reaction by which CO_2—exclusive of that introduced as carbonate in the ore and as gaseous constituent of the charcoal—is formed, whether by direct reduction of ore in the lower parts or indirectly by oxidation of CO in the upper parts of the furnace. He calls these two quantities of carbon D and I respectively, and their proportion is expressed by $\frac{D}{I}$ in the following tables.

In these the first six and two last vertical columns refer to those conditions of the furnace under which the observations under I., II., III., IV., V., VI., X., XI., in table No. 1 were made; the 7th, 8th, and 9th to hypothetical conditions to be referred to hereafter.

We notice how the increase of pressure—to which corresponds an increase of the quantity of blast per minute—is accompanied by a smaller consumption of fuel and a higher temperature of the gas, which means a higher temperature throughout the furnace and a larger zone of indirect reduction.

The heat by oxydation of C, notwithstanding the greatly different quantities of charcoal used, is not much altered, owing to the more or less advantageous way in which it is generated. With a low pressure the blast does not penetrate into the centre of the hearth, but rises along the sides of the furnace. As a consequence, a column of imperfectly reduced ore mixed with charcoal comes down in the centre, and has to be reduced directly by solid carbon. As only part of the ore is acted on by a very great body of gas, a large quantity of CO must remain inactive, and escape without being further oxidised. With increased pressure, however, the blast penetrates deeper into the crucible, the column of imperfectly prepared ore will be less, and the quantity of carbon used for direct reduction, as indicated in the tables by the lesser value of $\frac{D}{I}$, is diminished. The absorption of heat which accompanies direct reduction will also be less; therefore, the temperature at the tuyeres, and, in consequence, the temperature of the whole furnace, will rise. The gas, although—up to a pressure of 190 millim.—less in quantity and richer in CO_2, acts on the ore within a larger space and at a more favourable temperature, and is so enabled still to perform its duty.

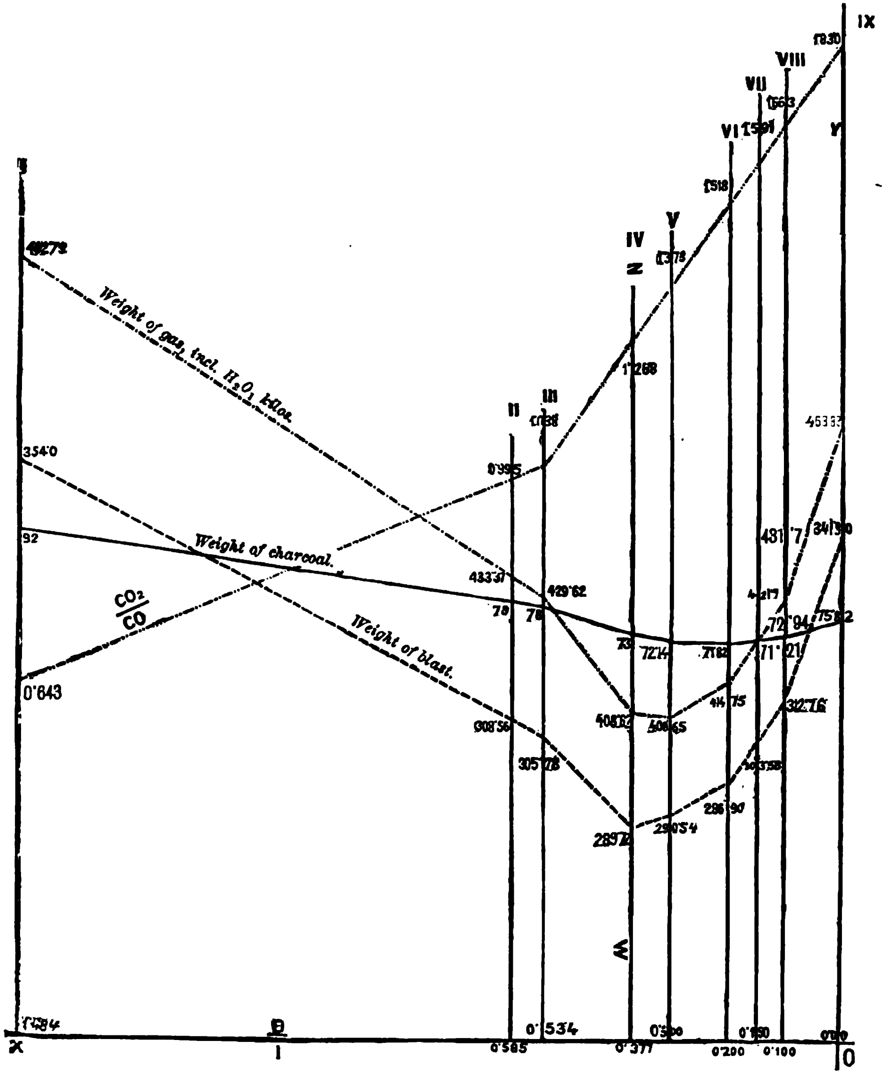
A good insight into these different relations between the quantities of fuel, blast and gas per 100 pig iron, and the nature of the reduction will be gained by an examination of the annexed diagram; the abscissæ represent the different values of $\frac{D}{I}$ (C oxidised directly, di-

TABLE NO. 2.

No.	Per 100 Tons of Pig-iron.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
1	Pressure of blast	90 mm	135 mm.	165 mm.	190 mm.	200 mm.	210 mm.	Hypothet Fur	ical Con- nace	ditions of Work.	190 mm.	195 mm.
2	Dry blast per 100 pig-iron	354·60	308·56	305·78	289·72	290·54	296·90	303·58	312·76	341·90	293·05	290·00
3	Temperature of blast °C	150°	150°	150°	150°	150°	150°	150°	150°	150°	150°	150°
4	Make per 24 hours	19·7 tons	23·0 tons	26·6 tons	30·0 tons	34·0 tons	35·0 tons	35·0 tons	35·0 tons	35·0 tons	36·0 tons	30·0 tons
5	Minutes required to produce 100 pig-iron	7·31 m	6·26 m.	5·41 m.	4·8 m.	4·2 m.	4·1 m.	4·1 m.	4·1 m.	4·1 m.	4·0 m.	...
6	Charcoal used for 100 pig	92	79	78	73	72·14	71·82	71·21	72·94	75·82	69·00	77 kilos.
7	Weight of gas per do.	492·73	433·37	429·62	408·62	408·65	414·75	421·83	431·73	463·83	408·11	408·00
8	Temperature of gases °C	300°	320°	330°	350°	370°	445°	514°	572°	725°	450°	320°
9	CO generated before tuyeres	146·56	127·66	126·52	119·88	120·22	122·85	125·61	129·41	141·47	121·94	...
10	CO in gases	128·01	93·88	91·13	78·21	75·48	71·62	70·54	69·49	67·73	61·12	...
11	CO_2 generated by indirect reduction	29·15	53·07	55·61	65·48	71·87	82·09	88·44	95·77	114·98	95·57	...
12	CO_2 generated by direct reduction	43·13	30·99	29·71	24 75	21·56	16·43	13·27	9·58	0·00	9·18	...
13	Proportion $\left.\frac{CO_2}{CO}\right\}$	0·643	0·995	1·038	1·268	1·373	1·518	1·591	1·663	1·830	1·850	0·880
14	Proportion $\left.\frac{D}{I}\right\}$	1·484	0·585	0·534	0·377	0·300	0·200	0·150	0·100	0·00	0·095	1·100
15	Blast per minute, kilos	48·4	49·3	56·7	61·0	69·1	71·4	74·0	76·3	83·4	73·71	...

TABLE NO. 3.

No.	$\frac{CO_2}{CO}$=	I. 0·643	II. 0·995	III. 1·033	IV. 1·268	V. 1·373	VI 1·518	VII. 1·591	VIII. 1·663	IX 1·830	X. 1·850
	A. *Heat Development* :—										
1	By Formation of CO at the tuyeres	155,329	135,298	134,086	127,063	125,928	130,204	133,146	137,177	149,938	129,239
2	By indirect oxidation of CO=($\frac{7}{11}$ I) to CO_2	44,575	81,125	85,066	100,141	109,897	125,440	135,242	146,455	175,827	146,174
3	By direct oxidat. of Carbon (=D) to CO_2	95,021	68,356	65,448	54,459	47,510	36,198	29,249	21,089	...	20,200
4	By hot blast	12,776	11,130	11,029	10,450	10,481	10,709	10,951	11,282	12,333	10,571
5	By hot ore (200° C)	7,010	7,010	7,010	7,010	7,010	7,010	7,010	7,010	7,010	7,010
	Total calories	314,711	302,919	302,639	299,123	300,826	309,661	315,589	323,013	345,108	313,194
	B. *Heat Absorption* :—										
1	Reduction and fusion of pig-iron	210,350	210,350	210,350	210,350	210,350	210,350	210,350	210,350	210,350	210,350
2	Fusion of slag, decomposition of $CaCO_3$, evaporation of H_2O, decomposition of H_2O in blast	39,056	37,460	37,377	36,768	36,787	36,873	37,050	37,246	37,979	36,662
3	Carried off by gases	36,090	33,626	34,353	34,545	36,475	44,501	52,249	59,468	80,830	44,032
4	Lost by radiation (by difference)	29,215	21,483	20,559	17,400	17,215	17,937	15,949	15,949	15,949	22,150
	Total calories	314,711	302,919	302,639	299,123	300,826	309,661	315,598	323,013	345,180	313,194


Weight of gas, incl. H_2O, kilos.
Weight of charcoal.
Weight of blast.
$\frac{CO_2}{CO}$
492·73
354·0
92
0·643
433·37
429·62
408·56
305·78
289·72
290·54
296·90
303·58
312·76
341·90
408·62
408·65
414·75
431·7
463·63
78
78
73
72·14
71·82
71·21
72·84
75·82
0·995
1·038
1·268
1·378
1·518
1·591
1·663
1·830
I
II
III
IV
V
VI
VII
VIII
IX
X
Y
Z
W
0·585
0·534
0·377
0·300
0·200
0·150
0·100
0·000
0

vided by C oxidised indirectly), while on the verticals are marked off the corresponding values for fuel, blast, gas, and the proportion $\frac{CO_2}{CO}$.

The first six ordinates refer to examples which have been tried practically. The question now suggested itself whether from a further increase of the pressure, everything else remaining unaltered, a further saving of fuel may be expected, and with which values for $\frac{CO_2}{CO}$ and $\frac{D}{I}$ the lowest requirement of fuel must be looked for. The most economical consumption of fuel will naturally be expected when $\frac{D}{I} = 0$, viz., when no direct reduction takes place. By a process analogous, or rather inverse to, that used in computing $\frac{D}{I}$ from the experimental data in the first six examples, but into the particulars of which the space at our disposal does not allow us to enter, Mr. Schellhammer finds for $\frac{D}{I} = 0$, $\frac{D}{I} = \cdot 100$ and $\frac{D}{I} = \cdot 150$ the several values given under VII., VIII. and IX. in the tables and the diagram. Although some of the fundamental assumptions (amongst them a daily production of 35 tons in all three cases) are not based on practical observations, some valuable conclusions may nevertheless be arrived at.

What must first strike us is that the minimum of fuel in the results so obtained is not as we expected, required with $\frac{D}{I} = 0$, viz., when no direct reduction occurs, but with $\frac{D}{I} = \cdot 200$. This, however, is explained by our assumption for all cases of equal size of tuyeres, equal temperature of blast, and equal quality of metal produced,—conditions which, we must conclude, are not the most favourable for the working of this furnace without direct reduction. The consumption of coal, rapidly decreasing at the first additions to the pressure, reaches a limit after which it rises again. With it rises the quantity of blast and gas per 100 kilos. of pig, and, above all, the temperature of the escaping gases. When $\frac{D}{I} = 0$ we find $\frac{CO_2}{CO} = 1{\cdot}83$, or equal to the proportion at which, according to Von Tunner and Debray, the mixture has no more reducing power. At the high temperature of 725° C., at which, even at the throat of the furnace, it comes into contact with the fuel, it would necessarily carry off part of the carbon as CO. Therefore this composition of the gas, if it were the result of the furnace work, would be modified by this action, so that in reality it could not exist at this temperature of 725° C. at the throat of the furnace. We must therefore conclude that a working of this furnace, under the assumed conditions, is not possible.

It does not, however, follow that a working without direct reduction is impossible under all conditions; certain modifications may lead to that result.

We have given in No. X. of the first table a modification of the working of the same furnace corresponding to No. IV. in so far as the same pressure of blast was used, but the tuyeres were enlarged to sixty-six millims. Here, in every respect, the best results were obtained, as is apparent from the data given on table No. 1, and the calculated values for heat absorption and development given under X. in tables 2 and 3. The proportion of CO_2 has in reality reached the limit at which reduction is possible; direct reduction is nearly absent, $\left(\frac{D}{I} = {\cdot}095\right)$ and the highest production is reached at a moderate pressure. The higher production is the natural consequence of about nineteen per cent. more air entering the furnace per minute than was the case in No. IV. The absence of direct reduction is probably owing to the even distribution of the gas throughout the furnace, as the pressure and quantity is just what is needed for its size. If the pressure remained the same, but by a reduction of the size of the tuyeres the jets of air were more contracted, the main current of the resulting gas would probably find certain easy passages in the furnace, and not thoroughly permeate those parts where the ore lies closer. A high pressure will aid the gas in penetrating into the pores of the ore, and by the more intimate contact an energetic reaction is promoted, but in every part of the furnace an even speed of the rising gases and of the descending solids should prevail. It remains to compare the results obtained under the last considered conditions, viz., when using 190 millim. pressure and tuyeres of 66 millim. with those of example VI., in which the same quantity of blast is thrown into the furnace per minute by means of narrower tuyeres at a higher pressure (210 millim.) A great similarity in most respects is apparent from a glance at the tables, except with regard to the mode of reduction, which in the latter case is to a considerable extent direct. As pointed out above, the focus of energetic combustion must here be of a narrow, conical shape, while with a lower pressure and larger tuyeres it is broader and spreads more within the hearth. It will therefore be less likely that the accumulation of material at the furnace sides, between neighbouring tuyeres, would remain insufficiently acted on. The author put this view to a practical test, and estimated the extent of the region of intense combustion by thrusting iron bars across the hearth, and judging the distribution of temperature in it by the extent to which they were found to be heated on withdrawing them. He obtained the greatest breadth when the pressure was 180 millim. and the tuyeres of 60 millim. diameter: the horizontal diameter of the focus was then about 52 centimetres, and its centre had the same distance from the corresponding tuyere mouth.*

We have seen that a slight modification of one of the factors on which the working of the furnace depends, has brought about an important change, in this case an improvement, of its whole economy. Modifications of any of the other conditions, be it the temperature of the blast or the shape and size of the furnace, will in different ways influence the results obtained: in every case, however, judicious trials will show the conditions of greatest economy. The mode of conducting the same furnace as developed by its gradual deformation towards the end of the campaign which preceded the above recorded experiments is shown in table No. 1 under XI. Here the proportion $\frac{CO_2}{CO}$ is as low as ·88 and the proportion $\frac{D}{I} = 1{\cdot}1$; in other words, more than half of the CO_2 is formed by direct reduction.

For full details of Herr Schellhammer's researches, see the *Oest. Zeitschrift für Berg- und Hüttenwesen* 1882, 35–42.

The Vienna Polytechnicum.†—This Institution has at the present time about 1400 students, 28 professors in ordinary, 7 extraordinary professors, 31 *Privat-docenten* and other teachers, and 27 assistants. It comprises four distinct schools, or as we might say *faculties*, the *Ingenieurschule* for roads, railways, and hydraulic engineering, the *Bauschule* for building and architecture, the *Maschinenbauschule* for mechanical work generally, and the *Chemische Schule* for technical chemistry. The full curriculum in the first two departments covers five years, in the two latter four years. It will be remembered, of course, that the instruction in an institution of this kind is not intended to *supplement* practical work, as in home engineering schools, but rather to take the place of it altogether. A young man who has finished his course at the Polytechnicum, although he has done nothing which we should call "practical work," is in the same position as is, in England, a young man who has finished his "time." Both are supposed to be prepared to go into an office or works and commence the earning of a salary. Under these circumstances collections of models which are quite unknown in England, and which are, in fact, almost entirely unnecessary under English conditions, form an important and essential feature in every German Polytechnicum. The student has to learn from them, as far as he can, what an English apprentice learns by seeing and handling actual machines themselves in the workshops.

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* The author unfortunately omits to make any mention of the dimensions of the furnace, and even of its locality.

† *Engineering*, Oct. 6th, 1882.

The mechanical or engineering laboratory, which was instituted by Professor Karl Jenny about ten years ago, and remains under his care, contains three testing machines. Of these one is an old single-lever vertical machine, of somewhat primitive form. It is used only for small loads up to 15 tons. The lever is a wooden beam divided in the ratio 1:10 with main knife edges 10 in. wide, the maximum pressure being therefore only 1·5 tons per inch length. There is no sliding weight, the weights being simply placed on a scale pan as required, the elongation of the piece being taken up by screws connected to the crosshead holding its lower end. Pains have been taken to secure that the piece should be held truly axially and so forth, but practically the machine is used now only for wire, belts, ropes, &c. The machines are both of the Werder pattern.

B.—STATISTICS, &c.

Ores.—The official statistics of the production of iron ore, iron and steel in Austria, for the year 1881, have been published,* and show that the past year has been one of considerable prosperity. The production of iron ore has been as under, excluding Hungary:—

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* Statistiches Jahrbuch des K. K. Ackerbau Ministeriums für 1881.

Statistics of Iron Ore Production in Austria.

Province.	Number of Workings.		Quantities Produced.	Value.		Number of Persons Employed.	Average Annual Production per Person.
	Total.	Being Worked.		Total.	Average Price per metric cwt* at Mines.		
			Tons.	Florins.	Kreuzers.†		Tons.
Bohemia.	111	26	70,206	146,622	20·9	542	129
Lower Austria	5	2	550	1,250	22·7	18	30
Upper Austria	2	...	...	...	...	...	...
Salzburg.	7	1	3,837	10,361	27·0	44	87
Moravia.	23	7	11,401	51,522	45·2	206	55
Silesia	11	5	7,011	39,083	55·7	247	28
Bucovina	4	1	701	...	...	...	4
Styria	33	15	420,974	1,090,424	25·8	2,209	190
Carinthia	10	5	88,041	354,862	40·0	665	132
Tyrol	7	2	1,706	12,399	72·6	47	36
Krain	17	10	8,268	55,333	66·9	283	29
Galicia	11	3	6,264	26,346	42·0	249	25
Total, Austria	241	77	618,963	1,788,202	28·9	4,510	137

Pig Iron.—Of pig iron, the aggregate production in Austria during 1881 was 379,639 tons, being a considerable increase on that of any recent year. Of this quantity, 337,843 tons were forge iron and 41,796 tons were foundry. It will be noted that, if the production of pig iron is divided into the production of iron ore, the average consumption of ore per ton of pig would appear to be only 1·63 tons, which is, of course, quite an abnormal figure. The fact is, that the actual consumption of ore has been considerably larger, and the extraneous supplies have been drawn from Hungary,‡ of which, however, we have not the statistics for a later year than 1880. Details of the pig iron production of 1881 are appended:—

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* 10 metric cwts. = 1 metric ton.

† 107 kreuzers = 1 florin = 2s.

‡ Mr. Kupelwieser informs us that the Witkowitz works in Moravia are now drawing a considerable part of their ore supplies from a newly-developed district in Hungary, the distance from mines to works being over 200 miles.

Statistics of Pig Iron Production for 1881.

Province.	Number of Furnaces.		Quantities Produced.			Value.	Average Price per Metric cwt. at Furnaces.				Number of Persons Employed.
	In Blast.	Out of Blast.	Forge Pig.	Foundry Pig.	Total.		Forge Pig.		Foundry Pig.		
			Tons.	Tons.	Tons.	Florins.	Fl.	Kr.	Fl.	Kr.	
Bohemia . .	11	27	43,857	13,790	57,648	2,911,903	4	46·6	6	91·0	3,102
Lower Austria .	2	3	15,501	94	15,596	624,569	3	96·0	10	...	99
Upper Austria .	...	...	...	...	...	...	..	...	...	...	...
Salzburg . .	1	2	694	716	1,411	70,581	4	60·0	5	39·2	56
Moravia . .	10	11	64,147	15,834	79,982	3,129,297	3	78·7	4	41·0	1,760
Silesia . .	6	1	30,156	3,032	33,189	1,594,386	4	31·1	9	69·6	732
Bucovina . .	...	4	...	...	...	...	...	...	...	...	...
Styria. . .	28	7	132,847	2,984	135,831	6,120,829	4	49·6	4	95·0	883
Carinthia . .	11	12	44,933	495	45,428	2,340,574	5	13·7	6	54·9	608
Tyrol . . .	1	3	429	27	456	21,646	4	73·3	4	80·0	11
Krain . . .	3	7	3,428	660	4,089	284,828	6	96·6	6	95·9	249
Galicia . .	3	2	1,845	4,158	6,004	472,896	4	38·0	9	41·0	605
Total, Austria .	76	79	337,843	41,796	379,639	17,571,449	4	42·7	6	25·3	8,105
Hungary, 1880 .	68	40	132,824	11,107	143,931	5,729,608	3	63·0	8	14·0	...
Total, Austria and Hungary .	144	119	470,668	52,903	523,571	23,301,057	4	20·0	6	65·0	...

The production of wrought iron, &c., during 1881, is not given in the publication whence the above figures are quoted; but from another source we learn that the quantity of steel turned out has been about 130,000 tons, of which 65,184 were produced at the Works of the "Oesterreichische Alpine Montan Gesellschaft." *

Coal.—Of mineral fuel the total output in Austria during 1881 was 15,304,813 tons, of which 6,343,315 tons were coal, and 8,961,498 tons were lignite. The following details of the coal industry are interesting:—

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* Including the works of Donawitz and Neuberg, for a description of which see p. 614, *ante.*

Statistics of Coal Production in 1881.

Province.	Number of Undertakings.		Quantity of Coal Produced.	Value.		Number of Persons Em-ployed.	Average Annual Production per Person.	
	Total.	Being Work'd		Total.	Average Price per Metric cwt. at Mines.		Quantity.	Value.
			Tons.	Florins.	Kreuzers.		Tons.	Florins.
Bohemia . .	287	119	3,417,632	10,199,300	29·84	18,832	181	541·6
Lower Austria	22	11	44,366	291,506	65·70	539	82	541·0
Upper Austria	2	1	...	...	...	20	...	...
Moravia . .	17	14	792,529	3,390,904	42·79	4,124	192	822·0
Silesia . . .	17	16	1,749,598	6,121,363	34·98	11,832	147	517·0
Styria . . .	1	1	279	2,120	76·0	4	68	530·0
Krain . . .	2	...	...	...	...	2	...	...
Galicia . . .	17	6	338,910	731,148	21·57	1,760	192	415·0
Total, Austria	365	168	6,343,315	20,736,431	32·69	37,113	170	558·7
Hungary, 1880	...	...	805,047	4,167,936	52·0	...	...	...
Total, Austria and Hungary	...	...	7,148,363	24,904,367	34·81	...	...	...

In the mining of lignite, 29,083 persons were employed, the average annual production per head being 308 tons. There are 930 lignite mines in Austria, of which in 1881 only 352 were being worked.

Imports and Exports.—The following is a statement of the Austrian exports and imports of iron and steel during the first half of the current year, compared with the corresponding period of last year :—

	Imports.		Exports.	
	1882.	1881.	1882.	1881.
	Tons.	Tons.	Tons.	Tons.
Old iron	63,858	28,304	1,310	1,096
Pig iron	125,818	48,051	2,254	16,354
Bars	3,759	...	420	256
Unwrought iron	581	481	133	129
Iron and steel in bars	3,851	3,164	11,684	12,111
Rails	4,896	226	410	67
Cast iron pipes	4,934	4,018	24	42
Iron hoops	1,078	476	87	43
Iron and steel plates	2,638	1,599	3,140	3,810
Iron and steel wire	564	512	764	686
Ordinary foundry pig	5,408	3,972	1,884	1,838
Cutlery	29	30	4,383	4,938
Other iron and steel goods . . .	7,803	2,452	9,115	7,011

BELGIUM.

A.—METALLURGICAL TECHNOLOGY.

The Bessemer Steel Works of the "Société Cockerill."—These works had at the beginning of 1881 two pits, each provided with two six-ton converters. The output of each pit per twenty-four hours did not exceed 180 tons of ingots.

The necessity of increasing the production led to a transformation of one of the pits according to American principles: this arrangement aims at giving perfect independence to each of the three leading departments of the manufacture, to the fusion, to the blowing, and to the casting of the ingots.

The metal is supplied in the *molten* state directly from the four blast furnaces, the production of which is about 260 tons per day. It is run into ladles, in which, with the assistance of a hydraulic lift, it is taken to the mouths of the converters. In addition, one or two cupolas, placed on columns, and provided, as in America, with movable crucibles, supply 120 to 150 tons of pig iron which runs into the same ladle, and is taken by a locomotive to the lift. Thus there is a continuous supply of liquid pig iron ready to be converted.

For the *blowing*, two converters are provided, which are perfectly free on their supports. The bottoms, which last from 12 to 14 charges, can be replaced within three quarters of an hour, so that one of the converters is always in readiness for the reception of a fresh charge.

Finally, the *casting* is carried on in a pit, or rather a circular trench, with the help of a central crane and ladles which are continually replaced; 12 or 14 of the latter are provided for this pit. Three cranes suffice to place the ingots on trucks, which convey them by a railway directly to the blooming shed.

It frequently occurs that the ingots of one cast are stripped while those of the next are being run. At the same time a third charge is just finished in the converter, and a fourth on its road to the converter. Such a continuous rotation of the work leads to an emulation in the several departments which essentially assists in bringing about an enormous increase of the output.

The effect of the new plant, which was started in June 1881, made itself very soon known. The production of this pit, called "the American," quickly came up to 250 tons of ingots in 24 hours; gradually it rose to 300 tons, and now it is 340. The highest production reached has been 391 tons, and this might be attained every day if the appliances for the manufacture of the ingots into rails required it.

Each cast yields 3700 kilos. of steel. The number of casts is 60 in 24 hours. The weight of each ingot is not higher than 825 kilos., and on an average is only 765 kilos. The expense of altering one of the old pits to the American plan was not above 72,000 francs.

Champney's Process of Manufacturing Steel Matrices.—M. de Housse, at a meeting of the Liége Society of Engineers (7th May 1882), gave a description of this ingenious method of making steel matrices, the use of which of late years has become general. They are applied as well for the stamping of small objects—as coins, buttons, spoons, jewellery, medals, &c.—as for the forging by pressure of iron and steel parts for sewing machines, bicycles, carriages, railway wagons, and locomotives. The process simply consists, first in the preparation of an exact model of the article for the making of which the matrix is intended; and secondly, in making an impression of this model in a block of cast steel heated to an appropriate temperature and protected from access of air.

In cases where articles have only to be copied, such as medals, coins, &c., these may serve as models—even silver and gold are sufficiently hard for the purpose. If, however, matrices for new shapes or objects are required, patterns have to be made of cast iron and properly finished. The pattern is fastened below the head plate of the steam hammer or monkey, which by its fall has to produce the impression. The piece of steel intended to form the matrix is usually made with a conically raised head of dimensions regulated by experience. It is put into the heating furnace on a fire-clay plate and covered with a fire-clay bell, a few drops of oil being poured on the former in order to create a reducing atmosphere around the block. When sufficiently hot it is removed from the furnace—still resting on the plate and covered by the bell—and taken to the anvil. This, for the reception of the block, is provided with a central cavity which can be quickly closed as soon as the heated block has been dropped or placed into it. The hammer or monkey, with the pattern in proper position, is then quickly allowed to drop, when in going down it will, by means of a simple lever mechanism, remove the cover and hit the bared steel block. Not more than one blow is required, and an arrangement is made to prevent a second blow which would be consequent on the rebounding of the hammer.

Mr. Champney's patent is said to have been acquired by six Governments, and a company exists in London which undertakes the making of matrices, according to design or model, for a great variety of industrial applications.

On the Brittleness of Iron and Steel at Elevated Temperatures. — (*Stahl und Eisen,* 1882, from the *Annales Industrielles.*)—Charles Walrand has made some comparative trials on the properties of certain varieties of iron and steel at ordinary temperature and at a temperature of 325° C. (617° F.) Without exception he observed at this higher temperature a remarkable increase in the brittleness and tensile strength of the metals and a decrease of the elasticity. He experimented with bars of one square centim. section, at ordinary temperature and at a blue tempering heat (equal to 325° C.) Bars of Swedish and Creusot iron, of boiler-plate and ship angle steel, could be bent double, when cold, without change in the appearance of the surface; cannon and spring steel broke when bent a little short of 180°. When heated, however, to 325° C., the Swedish iron, on bending, showed a series of cracks on the surface; Creusot iron and cannon steel broke when bent to 90°, boiler-plate steel when bent to 105°, angle steel when bent to 120°, and spring steel when bent to 55°.

The change of tenacity and ductility, as manifesting itself in rupture tests, is shown in the following table:—

Quality.	Ordinary Temperature.		Temperature of 325° C. (617° F.)	
	Tensile strength.	Elongation.	Tensile strength.	Elongation.
	Kilos.	Per cent.	Kilos.	Per cent.
Swedish Iron .	35·8	30·5	47·3	19·0
Creusot Iron, No. 7	36·7	30·5	48·2	16·5
Boiler Plate Steel	42·3	32·1	54·2	19·0
Angle Steel . .	51·8	27·6	64·9	15·0
Cannon Steel. .	62·3	22·3	75·2	12·0
Spring Steel . .	72·8	18·5	86·3	10·0

This peculiar behaviour, in Mr. Walrand's opinion, may explain many mysterious fractures, particularly of tyres. These, when subjected to the friction of powerful brakes, may sometimes become sufficiently heated to bring into play the above phenomena. The author examined a number of tender-tyres which were broken in an unexplained manner. They showed deep impressions of the brake. On being tested by a falling weight, fracture took place without previous bending; and, on turning, it became apparent that numerous fine cracks extended to a considerable depth of the metal. The surface within these cracks was partly oxidised, an evident proof that they had been in a heated condition.

Bicheroux's System applied to Puddling Furnaces.—(*Stahl und Eisen, September* 1882, from *Annales Industrielles.*)—At the Ougrée Ironworks the fifteen puddling furnaces were in 1877 changed to Bicheroux's system of firing, and have since given in every respect most satisfactory results. Although a very great saving of fuel has been effected, as compared with the old system, still the waste heat of these fifteen furnaces suffices to produce the steam for the whole of the engines, representing 460 horse-power, which are required for two cogging mills, a plate mill, a mill for merchant iron and a tyre mill, with their auxiliary machinery.

Each furnace has its generator and combustion chamber in which the gas and air, the latter heated by first serving as cooling agent for the hearth of the furnace, are mixed.

The dimensions of the different parts have to be nicely adapted to the quality of the coal, which may be of a most inferior description; even the smallest coal and slaty coal can be used.

The gas-producer has parallel sides, and is about the width of the furnace hearth. The grate is slightly inclined and accessible from the pit in front of it. Four small openings, usually closed by firebricks or lumps of coal, serve to charge the generator.

The gas is conveyed by a short horizontal flue to the vertical slit in front of the furnace hearth, which is also provided with a number of small openings for the admission of the heated air, so that a perfect combustion is accomplished in this place. Gas, as well as air, circulate by chimney draught only. After serving in the furnace, the hot gas enters the boiler flues in the usual manner.

The chief advantages of the system consist:—

1. In a great saving of fuel, as regards quantity and quality. Almost every fuel is suitable, even a coal with only 18 to 20 per cent. of volatile constituents giving excellent results. The white pig of Ougrée, with the old puddling furnaces, required 90 to 100 parts of coal for 100 of fibrous wrought iron, and 130 to 150 for 100 of fine-grained iron. With the new system only 60 and 80 parts are used respectively.

2. Diminution of the waste in puddling by 3 to 4 per cent., and improvement in the product.

3. Less repairs, as the fuel and its ash do not come in contact with the fire-bridge.

4. Few fire-bars are needed, as they are not exposed to an intense heat. After five months' use they were found almost intact.

5. Easier working of the puddling furnace, so that if the same wages were paid as when the old furnaces were used, the men could make 25 to 30 per cent. more.

It has been found of advantage to modify the puddling furnace itself, so that the hearth has been somewhat enlarged, and two working doors, opposite each other, have been provided. This has been found a great convenience, and this enlarged furnace produces nearly as much as two of the old furnaces. Most of the old castings could be worked into the new furnaces. The puddlers soon become used to the improved plant, and the number of first hands could be reduced to one half. The cost of one furnace amounted to nearly 2000 francs (£80). The working of one week at Ougrée shows the following results:—

Quality.	Coal.	Pig Iron.	Products.
	Kilos.	Kilos.	Kilos.
Wrought iron, No. 2 .	37,572	72,800	67,837
,, ,, No. 3 .	41,713	72,000	66,588
Fine-grained iron . .	117,958	166,400	155,810

Or, per 1000 kilos. of product:—

Quality.	Coal.	Pig Iron.	Production per Furnace in 12 hours.
	Kilos.	Kilos.	Kilos.
Wrought iron, No. 2 .	533	1,073	2,713
,, ,, No. 3 .	627	1,087	2,561
Fine grained iron . .	757	1,068	2,164

Iron Joists for Supporting the Roof of Colliery Workings.— At a recent meeting of the Liége Society of Engineers, M. Guibal, the inventor of the well-known fan that bears his name, called the attention of the members to some joists of special section which would, in his opinion, usefully supersede timber supports in collieries. A shoe, having the form of the letter T, is placed on the floor of the driving, and receives the uprights of H section, provided with notches, in which fit projections in the shoe and also in the longitudinals. To the upper joists are fitted others of T section, which replace the cross timbers. This system involves no complicated fitting, but is quite simple to erect. The joists weigh about 30 lbs. to the yard, and are capable of sustaining a load of 15 cwt. in the middle without deflection. When the driving is abandoned the iron is taken out, thus saving 50 per cent. of the cost. Messieurs Deladrière and Passelecq admit the simplicity of this system, but are anxious to see whether extended experience shows it to be greatly superior to the ordinary timbering, while taking into account the cost of first putting up, maintenance, and the sale of the old iron.

B.—STATISTICS, &c.

Iron and Steel.—An official statement has been issued showing the production of iron and steel during the first half of the current year. The pig iron output was as under:—

	Tons.
Foundry pig	33,503
Forge pig	267,618
Hematite pig	58,602
	359,723

The finished iron production was as under:—

	Tons.
Rails and plates	70,853
Other classes of iron	182,916
	253,769

Of steel ingots 60,627 tons were made, from which 47,845 tons of rails, plates, &c., were rolled; but in this total the production of the Angleur Works is not included.

Coal.—M. Harzé, chief engineer of mines, has published a treatise on "The Development of the Coal Trade in Belgium and Neighbouring Countries between 1831 and 1880," in which he shows that in 1830 the country raised 6,233,517 tons of coal, and exported 2,057,050 tons. The number of persons employed in the mines was 49,500, and their average wage was 490 fr. per man, while they raised 127 tons per man per annum. In 1855 the output was 8,409,330 tons, and in 1880 it had increased to 16,866,698 tons. The exports, which were 2,974,349 tons in 1855, in 1880 had reached 5,739,865 tons, the highest yet reported. The number of men employed was 70,980 in 1865, and 102,932 in 1880, while the wages were 744 fr. in 1855, and 893 fr. in 1880, but in 1875 there were 110,720 persons employed, and their wages were 1353 fr. The imports, which in 1831 amounted to 2882 tons only, in 1855 reached 68,578 tons, and in 1880, 944,486 tons. M. Harzé gives the following statistics of the production of coal for the following countries :—

Year.	Belgium.	France.	Germany.
	Tons.	Tons.	Tons.
1831	2,305,016	1,508,902	1,699,645
1841	4,027,767	3,410,200	3,340,580
1851	6,233,517	1,485,034	6,040,991
1861	10,057,163	9,423,320	15,080,074
1871	13,733,176	13,258,921	32,843,289
1880	16,866,698	19,361,564	52,047,832

While Belgium, from 1850 to 1860, produced 9·1 per cent. of the output of the four principal countries, France 8 per cent., Germany 13 per cent., and England 69·9 per cent., the proportions from 1866 to 1870 were :—Belgium 8 per cent., France 8·2 per cent., Germany 17·2 per cent., and England 66·6 per cent. For the last quinquennial period the proportions were :—Belgium 7 per cent., France 8·1 per cent., Germany 21·1 per cent., and England 63·8 per cent. In Belgium, the consumption from 1831 to 1835 was only 499 kilos. per head of population, but between 1876 and 1880 it had risen to 2007 kilos.

FRANCE.

A.—METALLURGICAL TECHNOLOGY.

Treatment of Copper in the Bessemer Converter (*Revue Universelle,* XII., 213).—In the smelting of copper, as well as of iron ores, a raw product is first obtained in a blast furnace which contains the whole of the metal in an impure condition, viz., in the case of copper, combined with iron and sulphur, while the gangue is carried off as slag. Attempts have been made repeatedly to purify this raw metal or "matte," in a manner analogous to pig iron in the Bessemer converter, but till lately without success. The difficulty which has to be overcome consists in the very large quantity of impurities to be removed, ranging from forty to seventy-five per cent. of the raw material, and their low heat of combustion.

M. P. Manhès of Lyons, well known as the first producer of the copper-manganese alloys, has, after numerous experiments, succeeded in devising a practical solution of this problem.

The converter differs from that used for steel-making by having its tuyeres arranged horizontally at a certain distance above the bottom, as it was found that, before the metal was finished, a portion of it, freed from the combustible elements, would sink to the bottom of the converter and solidify through the cooling action of the blast. Another difficulty was found in the stiffness of the cinder, which consists mainly of oxidised iron combined with the silica of the lining, and silicious fluxes, which are added to increase its fluidity. If the matte is rich, *i.e.*, contains fifty to sixty per cent. of copper, a metal of not more than one and a half per cent. of impurities is obtained without difficulty; if, however, it is poor, containing only twenty-five to thirty per cent. of copper, it is necessary to interrupt the blow when it is brought to about sixty per cent. It is then separated from the slag and transferred into another converter to be further treated in the same manner as the richer metal.

A society has been formed for the working of the new process at Eguilles, near Sorgue. They own three blast furnaces for the smelting of the ore and remelting of the matte, and three converters, of the capacity of three-ton Bessemer converter. In these, however, not more than 1½ to 2 tons of raw material can be treated, on account of the large volume of slag formed in the process. The present production amounts to about 4 tons a day. With rich matte, a blow of fifteen to twenty minutes is sufficient; the sulphurous vapours then disappear, and the metal is cast into ingots. In treating poorer material, the contents of the converter, after a certain time of blowing, are run into moulds, where the metal separates from the cinder. After cooling, the former is remelted in a cupola for a second blow.

The slags enclose something like two or three per cent. of copper in grains. This, however, is not lost, as the whole of the slag is added as a flux in the smelting of fresh ore.

Not only iron and sulphur, but all other impurities, as lead, tin, antimony, arsenic, are oxidised and removed either in the slag or volatilised together with the sulphur. The metal resulting from the process is purer than ordinary raw copper (Chili raw metal contains about four per cent. impurities), which is produced in six to eight alternately reducing and oxidising operations.

Researches on the Ferric Hydrates.—(*D. Tommasi in Bulletin de la Société Chimique de Paris, August* 5, 1882.)—All the ferric hydrates appear divisible into two series, the red, A, and the yellow, B. The former is obtained on precipitating a ferric salt with potash, soda, or ammonia. Those of the B series is obtained by oxidising ferrous hydrate, magnetic hydrate, or ferrous carbonate. Series A readily dissolve even in the weakest acids, and presents the phenomenon of incandescence on ignition. Series B is sparingly soluble in acids, either dilute or concentrated, and does not present the phenomenon of incandescence. Ferric chloride dissolves the series A in great quantity, but does not dissolve the series B.

Heat due to Magnetisation.—(*M. Pilleux in Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, April* 3, 1882.)—The author has heated to above 200° the iron core of an electro-magnet, by causing it to be traversed by the alternate currents of a "Mériten" machine. On substituting for the iron, cores of non-magnetisable metals of different degrees of conductibility the heating was not produced. On operating with iron of different degrees of temper, and even with steel, he finds that the coercitive force of the cores increases the heating when they undergo the action of frequent magnetisations and demagnetisations. It is therefore to the magnetisation, and not to induction currents, that the considerable heating of electro-magnets in certain cases must be attributed. The coercitive force plays the same part as the resistance to the passage of electricity when wire is heated by the current of a battery.

Carbonic Oxide: its Poisonous Action and its Presence in Houses (*Moniteur Scientifique, Quesneville, May* 1882).—M. Gruber expresses the opinion that there is a grade of dilution below which this gas ceases to be dangerous. Foder's test—the reduction of palladium chloride—renders it possible to detect a proportion of carbonic oxide in the air four times smaller than what is sufficient to exert a poisonous action. M. Gruber has not succeeded in detecting this gas in the air of rooms heated with iron stoves.

Equivalent of Carbon determined by the Combustion of the Diamond (*Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, No.* 16, *April* 17, 1882).—Professor H. E. Roscoe states that he has employed the same arrangements as MM. Dumas and Stas, but has used Cape diamonds instead of Brazilian specimens. Cape diamonds do not contain a trace of hydrogen, though they leave a little ash. If oxygen = 15·96, carbon becomes 11·97. M. Dumas, on communicating the above results, remarked that if oxygen is represented by 16, carbon becomes 12·002, that is a whole number within $\frac{1}{6000}$ part.

Composition of the Skin of Pig Iron.—M. A. Jaumain communicates to the *Annales des Mines* (1882, p. 552) analyses of the scale and skin which can be detached from the surface of certain varieties of white pig iron. This quality of iron has a smooth surface when the furnace is working cold, and a more or less rough, scaly skin when the furnace is working hot and the slag very basic. The scales consist chiefly of oxidised iron combined with silicon and phosphorus. In the relative proportions of these elements, and of manganese and sulphur, they differ very much from the pig iron: all impurities are present in greater quantity except carbon, which is absent. The subjoined examples will sufficiently show their character:—

	Si	S	P	Mn	C	Fe	O
Pig iron . . .	·713	·308	·1798	trace	...	...	...
Scales	7·287	·687	5·145	·180	none	...	not estimated
Pig iron . . .	·46	...	1·90	·72	4·69	...	...
Scales	2·80	...	3·45	3·60	none	63·00	not estimated

According to the author's theory, the first step in the formation of these scales is the liquation of a metallic alloy containing the elements in the above proportions, and this alloy, through being exposed to the atmosphere, is oxidised.

Foundry iron with a rough surface is usually low in silicon, and on being remelted in the cupola is inclined to become white; it is therefore not liked by founders. M. Jaumain found the rough skin to contain occasionally twice as much silicon as the pig iron, but the P was found as low as a fourth of that of the pig iron. This quality is produced when the furnace is working irregularly, through masses of unreduced ore dropping into the metal contained in the crucible. A cast of this metal is frequently preceded by a black slag, which, however, does not necessarily differ in chemical composition much from that which accompanies a rich grey metal. Its content of iron is a little higher, and in some examples given by M. Jaumain there is 1·10 Fe in a grey slag with dark surface made from No. 2 and No. 3 iron, against 1·48 Fe in a black slag, similar in appearance to refinery slag, which accompanied white and mottled iron. These black slags frequently are cellular, and at their flow a strong smell of sulphurous acid is perceptible. In the author's opinion the gaseous content of the cells is sulphurous acid, for the presence of which he accounts, in agreement with M. Gruner, in the following manner:—When masses of imperfectly reduced mineral arrive in the hearth of the furnace, and are melted without being reduced, the oxide of iron will react on the calcium sulphide present in the normal slag and form calcium oxide, sulphurous acid, and iron sulphide. A minute quantity of the latter body suffices to produce the black colour of the slag, while the sulphurous acid forms the cavities.

In wide furnaces which are worked with low pressure of blast, a central column of imperfectly reduced mineral may be continually going down into the crucible, and, under ordinary circumstances, be perfectly reduced by solid carbon. As soon, however, as the furnace scaffolds, or there is a diminution of the blast pressure, a greater quantity arrives in the crucible, and the above described action on the slag and on the metal will take place. The latter undergoes a partial refining, as manifested in its lower quality and lower content in silicon. M. Jaumain made, in connection with the slag cells, an observation which proves that, if not sulphurous acid, at least an oxygenated gas is present in them. He noticed within the cells small globules of metal which were red on the surface, and therefore oxidised.

Influence of a Metal upon the Nature of the Surface of another Metal placed at a small Distance.—(*Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences*, No. 18, May 1, 1882. H. Pellat.) If two metallic surfaces are placed parallel to and at a little distance from each other (a few millimetres or a few tenths of a millimetre), each metal has generally undergone a slight change in the properties of its superficial layer, due to the neighbourhood of the other metal, and depending upon the nature of the latter. This change requires a few minutes for its production, increases with time, but tends towards a limit. When the influencing metal is removed, the one influenced returns by degrees and spontaneously to its original state. The phenomenon was detected by measuring the differences of potential that exist between the electric strata which cover the surfaces of two metals in contact. Amongst the influencing metals lead and iron produce the most considerable effects; copper, gold, and platinum give a distinct effect; zinc does not appear to modify a metallic surface placed near it. The phenomenon observed, though detected and studied electrically, is not of an electric character. It is a purely material action, depending essentially on the nature of the influencing metal, and is greatest with lead, less with copper, and *nil* with zinc. It appears as if metals gave off, at common temperatures, a volatile substance, which, when deposited upon the surface of objects, modifies their chemical nature. The author believes that this phenomenon approaches the images of Moser, and is connected with the fact that several metals have a slight odour.

Influence of the Coercitive Force upon the Heat produced by Magnetisation.—(*Les Mondes, Reoue Hebdomadaire des Sciences*, No. 14, 1882. L. Pilleux.)—A fragment of iron which is being magnetised becomes heated in an appreciable manner. The author proves that it is magnetisation and not the induction currents which heats the iron cores of electro-magnets, and the coercitive force of these cores plays in this case the same part as the resistance to the passage of electricity when a metal wire is heated by the current of the battery.

Easy Process of Magnetisation.—(*Les Mondes, Reoue Hebdomadaire des Sciennes*, No. 14, 1882.)—The so-called method of M. Elias, which has been used by M. Jamin, and carefully studied by M. Gaugain, is as follows:—A coil of thick wire is traversed by an intense current. It is composed of 10 to 20 spirals, and is very short in its axial dimensions. The plate or rod of steel to be magnetised, is passed through it, and a few passes suffice to give saturation.

Tests for Iron and Steel Plates prescribed by the French Admiralty.—(*Le Fer.*)—Iron plates, according to their quality and use, are divided into four classes. In testing, the load is applied in the direction of the least resistance, and the following results should be obtained:

Load per square Millimètre of original section.	1. Common Plates (tôles communes améliorées) for Chimneys, Floorings, &c.	2. Ordinary Plates (fers forts) for Boiler-casings, &c.	3. Best Plates (fers forts supérieurs) for Boiler Plates and Forgings, &c.	4. Best best Plates (tôles à bois), Head Plates, Fire Boxes, &c., of Boilers.
	Kilos.	Kilos.	Kilos.	Kilos.
Initial load	24	28	29	29
Minimum breaking load . .	25	28	29	30
Average do. do. . .	28	31	32	35*
Elongation, per cent. minimum	2·2	4·0	5·5	7·5
Do., average . .	3·5	5·0	7·0	10·0

The initial load has to be maintained for five minutes, the additions to the load have to be made at intervals of one minute. The test bars are of the thickness of the plates, and of 30 millimetres width, except for plates of 5 millimetres thickness, and below, when the width is 20 millims. The forge tests consist in rolling samples into cylinders, dishing out into deeper or shallower calottes, and bending at right angles.

Steel Plates are distinguished according to their destination for either constructive purposes or for boilers.

The following tests are exacted :—

Thickness of Plate in Millimetres.	Plates for Constructive Purposes.		Boiler Plates.	
	Minimum Breaking Load.	Final Elongation, Minimum per cent.	Minimum Breaking Load.	Final Elongation, Minimum per cent.
	Kilos.	Kilos.	Kilos.	Kilos.
1·5	47	10	...	...
2 to 5	47	12	...	...
3 „ 4	47	14	...	...
4 „ 5	46	16	...	...
5 „ 6	46	18	...	...
6 „ 8	45	20	42	24
8 „ 20	45	20	42	26
20 „ 30	44	20	40	25

An initial load equal to eight-tenths of the breaking strain, as given in the above table, is allowed to act for five minutes, and then the additional weights are put on every half minute. The bars are 2 metres long and 30 millimetres wide for plates of more than 5 millim., and 20 millim. wide for those less than 5 millim. thickness.

The forge tests are directed towards securing perfect hemispherical calottes. It is also demanded that, after tempering, boiler plates shall be bent double so that the two parts are perfectly close against each other; while in the case of plates for constructive purposes, a space of twice the thickness of the plates may be left between the two parts after bending.

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* A deficiency of 3 kilos. is allowed, provided it is compensated by an excess in elongation of 1·5 per cent. per kilo. of the deficiency.

Progress in Puddling.—(*Stahl und Eisen.*)—*L'Ancre de St. Dizier*, in comparing the present puddling practice with that customary in England fifty years ago, remarks on the small amount of progress which has taken place in this important metallurgical process. The modifications of the general form of furnaces are very trifling, mainly directed towards greater economy in the consumption of fuel; and a notable improvement in this respect, accompanied by an increase in the output, has been effected. The use of charcoal pig and of refined metal has been mostly abandoned. The waste in puddling used to be about 16 per cent., the consumption of coal 95 per cent.; at the present time the waste is about 13 per cent., the consumption of coal 82·5 per cent. The better yield, accompanied by an improved quality of the puddled product, is in a great measure due to the now general use of small quantities of basic fluxes in the process. When highly silicious pig iron is puddled by itself, the great waste of iron is owing to the circumstance that simultaneously with each atom of silicon so much iron is oxidised that a certain silicate results. If, however, additions of soda and lime are made, these bases will combine with the silica, and so save a certain portion of iron. At the same time this alcaline cinder remains fluid at a lower temperature than the pure silicate of iron, and therefore a more complete separation of cinder and metal, and greater freedom of the latter from the obnoxious admixture of cinder, is the result.

For a charge of 220 kilos. an addition of a well-pulverised mixture of 1·2 kilos. sodium bicarbonate and 8 kilos. lime should be made as soon as the pig iron begins to melt. A second addition of 8 kilos. sodium bicarbonate follows when the whole of the metal is melted. Peroxide of manganese promotes the decarburisation of the charge. 1·2 kilos. is a suitable quantity for this purpose. By these means the waste is lessened and the quality improved, and No. 3 puddled bars can be made from inferior qualities of pig iron.

Recovery of Vanadium from Slags.—(*Musée de l'Industrie*, xlii. p. 93.)—Messrs. Witz & Osmond, in a communication published in the *Comptes Rendus de l'Academie des Sciences de Paris* (XCV. No. 1, p. 42), draw attention to the fact that vanadium, an element of a chemical character similar to phosphorus, not unfrequently is a companion of the latter as a constituent of iron ores. The two will subsequently, in all phases of the manufacture, behave alike, and are found concentrated in several slags, notably those obtained in Messrs. Thomas & Gilchrist's modification of the Bessemer process. At the Creusôt works alone, something like 60,000 kilos. of vanadium might be recovered yearly from this source. The authors propose practical methods for the extraction of vanadates. Their most important use is at present in the dyeing of fast aniline blacks and the preparation of marking ink.

The Manufacture of Basic Steel at Creusot.—In the last issue of the *Journal*,* it was stated that M. Delafond had contributed to *Les Annales des Mines* an interesting paper on the manufacture of steel by the basic process at Creusôt. The author undertook to investigate this subject with the view of determining the suitability of basic steel for rails, and his report has been published at the instance of the Committee of permanent way for the State Railways. The employment of dolomitic bricks has, he says, been abandoned at Creusôt, where they now use a mixture of magnesian lime agglomerated by means of anhydrous gas tar. The analyses of the two descriptions of steel made at Creusôt show that basic steel contains less silicon, phosphorus, and sulphur than acid steel, while of carbon the content is higher in the former than in the latter. The average composition of each has been found to be as under:—

	Basic Steel.	Acid Steel.
Carbon	0·43	0·40
Silicon	trace	0·30
Manganese	0·76	0 66
Phosphorus	0·06	0·07
Sulphur	0·029	0·04

A series of tensile tests made at Creusôt show the following averages:—

	Basic Steel. Kilos.	Acid Steel. Kilos.
Breaking strain (per square mm.) . . .	72·00	73.20
Co-efficient of extension	16·10°/o	17·28°/o

These results show a slight advantage in favour of the acid steel. The limits obtained for the basic steel were, however, less than those obtained for the acid, and the results show rather more regularity in the dephosphorised metal. Tests made on twelve rails of basic and thirteen of acid steel showed an average deflection as under:—

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* *Vide* No. I., 1882, p. 337.

Charge in Tons.	Average Permanent Deflection.	
	Acid Steel. mm.	Basic Steel. mm.
10	0·17	0·07
15	0·3	0·13
17	0·51	0·23
20	0·92	0·46
25	8·4	6·2
30	25·3	21·2

Dynamic tests showed a deflection under a fall of a monkey weighing 6 cwt. of much the same extent in both kinds of steel, and as they appeared to be of much the same quality, the Minister of Public Works decided, by an order dated 9th December 1881, to admit both varieties of steel equally for the supply of State rail contracts.

Speaking of the physical structure of dephosphorised metal, the author states that in the first production of basic steel it was found that the surface of the ingots was covered with blisters of from two to three centimeters in depth. During the rolling these cavities quite disappeared, but their sides did not weld together. The top part of the rail presented thus a great number of imperceptible cracks, which were detrimental to its resistance. Fortunately this defect was remediable. It was discovered that those ingots coming from a cold blow were covered with blisters, whilst those from hot ones had only a very thin layer (two to three millimetres at most), which disappeared by oxidation during reheating. The remedy for this fault in the basic ingots was thus indicated. It was only necessary so to conduct the operation that the metal at the moment of pouring was at a high temperature. This was accomplished by the following means:—hot charges in the blast furnace; constructing calcining kilns near the converters, in order that the additions of lime might be at a high temperature; and by increasing the percentage of phosphorus in the pig treated. By the adoption of these measures the basic ingots have now no more superficial blisters than the acid ones. It may be remarked, before quitting this point, that these blisters are equally produced in acid operations, when the blow is cold. The following experiments, at which the author assisted at the Creusôt Works, clearly prove this. In two Bessemer converters, with acid linings, two simultaneous operations were carried on, the pig used being the same in both cases; the one blow was hot, whilst the other had been rendered cold by the addition of pig and scrap.* The ingots resulting from the cold blow had their surface covered with blisters for a height of about 25 millimetres, whilst this fault did not exist in the ingots from the hot blow. These experiments show, although it is difficult to explain it theoretically, that the temperature of the steel at the time of pouring plays a considerable part in the formation of blisters.

As to dephosphorisation in the reverberatory furnace, the author gives some interesting data. The furnace employed at Creusôt is the same as that used in the manufacture of Siemens-Martin steel, the only difference being that the bed is made of a mixture of magnesian lime of the same kind as that employed in the Bessemer converter. The roof is of silica bricks, a layer of bauxite being placed at the juncture of the magnesian lime and the bricks. The furnace is heated in the ordinary manner, by the combustion of gas from the Siemens generators. The charge of phosphoric pig is run in, and common iron dissolved gradually in the bath. The refining is produced under the influence of the current of gas, as in an ordinary operation. Lime is added, at three or four different times, in order to make the slag very basic. From time to time this slag is removed by means of a rake. Owing to this excess of base, silicon disappears completely, and phosphorus is almost totally eliminated. The different bodies disappear in the same order as in the Bessemer converter, so that the operation consists of the following successive periods; scorification, decarburisation, and after-blow. The moment of stopping the refining, and proceeding to recarburise by an addition of spiegel, is found by means of trial tests, as in the converter. One operation lasts about twelve hours, and about fifteen tons are obtained.

The advantages which the reverberatory furnace presents over the converter are thus described by the author—

1. The construction and repair of the basic hearth is much more easy.

2. The temperature of the bath is obtained independently of the combustion of silicon, carbon, phosphorus, &c., so that there is no necessity for treating a pig containing a high proportion of these bodies.

3. The slag is more easily removed by means of a rake, it being easy to remove it at any time during the operation, while in the converter it can only be removed when it has become fluid. The elimination of phos-

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* The following table shows the course of the operations:—

		Hot Blow.		Cold Blow.	
Metal taken direct from the blast furnace			6,500 kilos.		6,500 kilos.
Additions	Cold pig	600	1,000	1,600	2,500
	Steel scrap	400		900	
Spiegeleisen			400		480
	Total		7,900		9,480
Duration of blow			25 minutes		24 minutes.
Aspect of steel after pouring			Tranquil.		Rose in moulds.

phorus is also more assured, and the return of this body into the steel on the addition of spiegel is less to be feared.

4. The duration of the refining is longer, and the trial tests more easily taken, while the operation is more easily regulated. The manufacture of basic steel being thus easier in the reverberatory furnace than in the converter, Messrs. Schneider have, as before stated, been quite successful from the very commencement in making this metal in the Siemens-Martin furnace.

Metallurgists, adds the author, are now in possession of two different methods of manufacturing steel, both in the converter and in the reverberatory furnace, the one consisting in treating pure products in an apparatus furnished with a silicious lining, the other in treating impure products in presence of a basic lining. The following question, therefore, naturally seems to present itself: Since, other things being equal, linings of magnesium lime offer a more complete purification than silicious ones, why not treat all pig metal, even that resulting from pure ores, in a basic apparatus? By this means these latter should give a steel of very great purity. So far as concerns the reverberatory furnace, it appears probable that in the majority of cases the silicious hearth will be replaced by one of magnesian lime, the carrying out of a basic operation presenting, as explained above, no difficulties. But with the converter the case is different; it would not be found advantageous to treat in a basic lined converter metal such as that used in the acid process, since this metal is high in silicon, and this circumstance presents a grave obstacle. On the other hand, if the blast-furnace charges were so regulated that the resulting pig was but slightly silicious, there would probably not be sufficient heat generated by the molecular combustion to assure the liquidity of the bath and slag.

Manufacture of Aluminium (*Le Fer, June* 1882).—The only French works engaged in the manufacture of aluminium are the Salindres Chemical Works. Since 1862 from 1000 to 1800 kilos. have been made per annum.

B.—STATISTICS, &c.

Production of Iron and Steel in the First Half of 1882.—The *Administration des Mines* has published a table of the production of the mines, ironworks, &c., of France during the first half of 1882, which shows that the improvement in the iron trade has been considerable.

Comparing the results of the first half of this year with those of the latter half of last year, the following amounts of increase appear:—

	Tons.
Pig iron	47,676
Finished iron	19,970
Steel	15,578

Details are appended, the pig iron being classified according to the fuel used:—

	First Half of 1882.	Second Half of 1881.
	Tons.	Tons.
Forge Pig Iron—		
Coke	789,350	732,810
Charcoal	22,733	21,461
Mixed fuel	5,745	8,952
	817,828	763,223
Foundry Pig Iron—		
Coke	173,660	185,013
Charcoal	4,100	4,583
Mixed fuel	15,207	10,300
	192,967	199,896
Total Production of Pig Iron—		
Coke	963,010	917,823
Charcoal	26,833	26,044
Mixed fuel	20,952	19,252
	1,010,795	963,119
Finished Iron—		
Iron rails	15,183	13,279
Merchant iron, &c.	438,995	417,013
Iron plates	85,026	88,942
	539,204	519,234
Bessemer and Siemens Steel—		
Rails	161,687	151,984
Bars, &c.	37,256	36,329
Plates	9,422	6,310
Other Classes of Steel—		
Puddled	6,195	8,274
Blister	1,418	1,497
Crucible	4,478	3,484
	223,456	207,878

Coal in the Nord.—M. H. Peslin, chief engineer of mines, has issued his official report on the production of the mines in the Nord in 1881, which shows that the trade of that year was less satisfactory than that of 1880. The total output of coal was 3,671,702 tons, or 29,887 tons less than in the previous year, but larger than that of any year before 1880.

The number of persons employed was increased as under:—

	1881.	1880.	1879.	1878.
Below ground	16,026	16,098	15,243	16,157
Above ground	4,675	4,561	4,247	4,048
	20,701	20,659	19,490	20,205

The average production per miner for the year was 229 tons, or a little less than in 1880. The total wages paid in 1881 was 20,529,406 fr., which is about 991·70 fr. per man per annum. In 1880 the total wages amounted to 20,077,772 fr., or about 971·86 per man. The selling prices were a little below those of 1880. The following table gives a *resumé* of the report:—

		1881.	1880.
Concessions opened out or proved		16	16
Concessions unproved		5	5
Production	tons	3,671,702	3,701,589
Pits working		46	46
Pits sinking		3	4
Total number of persons employed		20,701	20,659
Production per man below ground	tons	229	230
Total wages	fr.	20,529,406	20,077,772
Average wages per workman	,,	991·70	971·86
Average wages per ton of coal got	,,	5·59	5·42
Selling price per ton	,,	11·34	11·37

The Longwy Blast Furnaces.—A recently published statement shows that in July 1882 there were twenty-three furnaces in blast, eight under construction, and only one inoperative in this district, where the iron trade is being largely extended.

GERMANY.

A.—METALLURGICAL TECHNOLOGY.

The Siemens-Martin Blow.—Professor Kupelwieser, in a recent lecture on this process before the Metallurgical Society at Leoben, referred in particular to the use of blast in connection with this process as introduced in 1879 by Herr Würtemberger at the Phoenix Works in Ruhrort. Here the blast is supplied by tuyeres which are introduced horizontally into the furnace and then turned down, so that the nozzles dip into the metal. The tuyeres are formed of iron tubes covered with fire-clay, and bent at the end where a fire-clay nozzle is attached. This at Ruhrort has one opening of 20 to 25 millim., but Herr Würtemberger recommends three blast outlets for each nozzle. Outside the furnace the tuyeres (three at Ruhrort) are attached to a cast-iron head, which by means of flexible tubing is connected to the supply of blast. The tuyere pipes, besides, are more securely held in position by a wrought-iron frame placed on the working plate, with the furnace door resting on it. This frame is slightly rounded, so that it can be turned in its place sufficiently when the nozzles have to be lowered or raised. It is fastened to the cast-iron head by two strong iron bands, which are joined in a bow by which the apparatus can be guided. The whole can be readily introduced into the furnace and withdrawn from it by means of a small overhead crane, which can be linked to a ring provided at the cast-iron head. This arrangement, which can be easily and cheaply applied to any existing steel furnaces, compares favourably for efficiency and cost with the systems of moving furnaces tried elsewhere for the same purpose. At Ruhrort the blowing machinery of the Bessemer plant is available for the requirements of the Siemens furnaces. A charge of 35 per cent. of white sparry iron and 65 per cent. scrap is melted in the furnace, and then, by means of the blast, the hardness of the metal is reduced to the desired degree. When using three tuyeres of 20 to 25 millim. diameter, a pressure of $\frac{3}{4}$ atmospheres and a blow of 15 to 20 minutes are sufficient to obtain a finished product of ·1 to ·2 per cent. carbon, and of a breaking strain of 41 to 47 kilos. per square millim. The blast is of particular advantage in the production of this soft metal, as the degree of decarburisation can be so nicely regulated. The temperature, in consequence of the energetic chemical action, is much above that prevailing in the ordinary process, as is evident by the appearance of a brown fume similar to that observed in hot Bessemer charges. Several hundredweight of cold rail-ends have frequently to be added. The final product, according to present experience, is superior to that obtained without blast. The thorough mixing of the metal results in perfectly homogeneous ingots, while, without this, the lower portion of a charge is somewhat higher in carbon than the upper portion.

Professor Kupelwieser is of opinion that a further development of this combined Bessemer and Siemens process would be of great advantage in the manufacture of steel, particularly from the white pig iron made with charcoal in the Alpine districts of Austria. These works, he considers, would do well, and will soon be obliged to extend their operations towards the production of soft ingot metal. The general character of the pig is well represented by the following analysis of white forge iron from Erzberg ore recently made at the Imperial Assay Office in Vienna :—

C = 3·482 Si = ·110 Mn = 1·728
Fe = 94·559 S = .029 P = ·062

It is evident that, from its lack of heat-producing elements, it is not suitable for the conversion by the Bessemer process, while with the additional heat of the Siemens furnace it might be successfully converted into steel by blowing. Only little slag would result, and under certain circumstances it might be finished without additions of scrap iron, the procuring of which, in sufficient quantity, would be difficult if a large increase of the production of open-hearth steel by the usual method should take place.

As regards the wear of the furnace, there is only in that part of the roof which is situated above the nozzles a greater wear, through the throwing up of particles of slag, than in furnaces worked without blast. This part has to be renewed after 70 or 80 charges. There is no difference perceptible in the brickwork of the regenerators.

Drawings of Würtemberger's tuyeres, and a full report of Professor Kupelwieser's lecture, are given in *Oest. Zeitschrift für Berg- und Hüttenwesen*, 1882, Nos. 25 and 26.

The Cavities in Cast Iron and Steel.—Dr. F. Müller of Brandenberg (*Stahl und Eisen*, November 1882) gives a full *resumé* of all researches hitherto published on the gaseous contents of iron and steel. He supplements the detailed description of his own valuable labours in 1878 and 1879, which were extended to a great variety of metals, by an account of what had been done before him by Messrs. Troost and Hautefeuille in 1873, by Parry in 1874, by Regnard in 1874, and after him by Messrs. Stead and Richards, and Stead and Gjers.

The author's chief purpose is to refute the objections raised at the conclusion of M. Pourcel's paper on solid steel castings (see this vol., p. 509), and the discussion following it, against his frequently pronounced view, that hydrogen and nitrogen, and not carbonic oxide, are the cause of the porosity of castings. Without exception, the specimens of gases examined by all investigators named above, contain hydrogen as a chief constituent, whether they were obtained by heating solid metal *in vacuo*, or drilling either solid or porous metal. In the case of about six samples of pig iron the hydrogen (about 75 per cent. by vol. of the gas) is accompanied by about 3 per cent. carbonic oxide, while the gases obtained from ingot steel and forged steel (except one specimen, examined by Parry, which *in vacuo* gave a gas with 24·3 carbonic oxide) are either free from carbonic oxide or contain minute quantities. The hydrogen, in all cases, is accompanied by about one-fifth its volume of nitrogen.

All facts which have so far become known in connection with this subject, cannot, in the author's opinion, be interpreted in any other way but that these two gases, which, originating from the blast, are held in solution by the liquid metal, become liberated from it by different circumstances: by solidification, in analogy to the separation of gases from freezing water, in which case the gas is retained in the cavities of the metal; by agitation and pouring; by creating in the liquid metal an evolution of carbonic oxide, as in adding spiegel to overblown steel. In this latter case the evolved CO carries off so much of the H and N that the metal which was previously saturated with these gases, is freed from them to such an extent that the residue is not more than can be held in combination with the solidified metal, and a solid ingot results.

Although large quantities of gas may separate on solidifying, still a certain quantity is retained in the solid metal—similarly, as on the crystallisation of a salt from a solution, the pure body separates in larger masses, while a certain portion of it remains diffused in the mother liquor. This latter—or a portion of it—is obtained when solid steel is heated *in vacuo*, or finely disintegrated; while the gas separated on solidifying in the larger cavities, can be obtained in larger quantities by drilling. The cavities, at ordinary temperatures, contain the gas in a compressed condition, 3 to 5 atmospheres pressure being observed.

Dr. Müller gives an ingenious explanation of the peculiar shape and arrangement of the cavities; also of the different means of preventing the honeycombing in steel, as by addition of silicon, which makes it more absorptive for the gas, and therefore able to retain it on solidifying, by pression, and by the addition of spiegel.

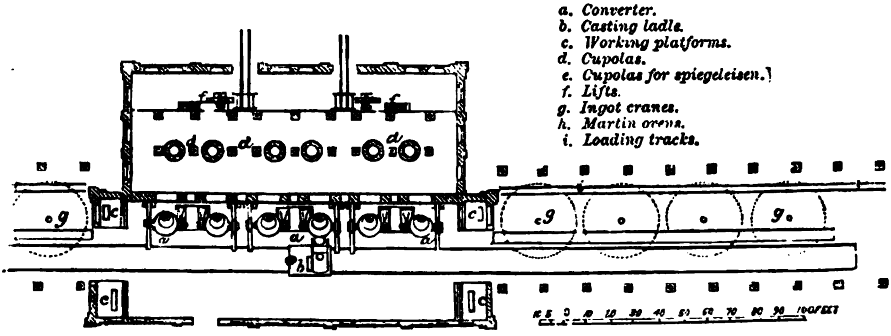
He combats the theory accepted by many that the cavities are owing to the intermolecular action of oxygen and carbon, so to say, the finish of the spiegel reaction. It is clearly disproved by the absence from the cavities of CO, the only gas which could result from such an action, and by the fact that overblown metal, which is practically free from carbon, is more honeycombed than any other. He regards the action of silicon as a merely physical one; it increases the absorptive power of the metal for the gases, so that a liquid steel which is saturated with gas becomes, by addition of silicon, unsaturated, and a secretion of gas does not take place on solidifying. The view of a chemical action between Si and FeO, resulting in a silicate, is untenable, as in the production of silicious steels (as mostly made in Germany), quantities of Si up to ·6 per cent. are left in the metal at the end of the blow, when carbon is eliminated and oxide is present. Nevertheless, such a metal, if cast into ingots without spiegel, yields very porous ingots; while if spiegel is added, a violent evolution of CO ensues. This shows that the oxide is quite indifferent to Si, but reacts immediately with carbon. It is also proved by analysis that only Mn and C disappear on the addition of silicious spiegel.

The author gives well-founded explanations for many of the phenomena connected with this practically important and scientifically interesting subject. For the full study of his views, however, we must refer our readers to the original, to which our limited space will not allow us to do justice.

The author finds that some recent analyses of Stead's, published in connection with Gjers' paper on "Soaking Pits" (see this vol. p. 565), fully confirm his formerly pronounced views. A comprehensive account of these, and nearly the whole of the analytical results obtained by Dr. Müller and others in the investigation of this subject, were given in J. Parry's paper on "Hydrogen and Carbonic Oxide in Iron and Steel" (*vide* the *Journal*, 1881, pp. 183, 720).

Kriegar's New Iron Foundry Cupola.—Kriegar's new foundry cupola, in Pintsch's works at Fuerstenwalde, is said to have been at work about 2½ years with economical results. The furnace is square in section, having a cast iron case, and is built up inside with fire-bricks, the lower part being covered with refractory sand. The blast enters by a curved pipe, fitted with a throttle-valve. In the door, which gives great facility for the manipulation of the materials, are eye-pieces, through which the working of the furnace may be observed. After two and a half years' work Mr. Pintsch says he doubts whether, for his purpose, namely, the production of very clean light castings, he could have a better cupola than Kriegar's. After it has been filled with coke at the commencement of the blow, he is able to melt 100 lbs. iron with 4½ lb. Westphalian coke, or with 5 lb. of Lower Silesian coke. The blower employed with the furnace is also Kriegar's, and works with 18-inch water column pressure. The process of melting begins after about twenty-five minutes, the furnace rendering a good hot iron, and an addition of 30 per cent. of wrought iron may be made. For a daily blow of from one to two hours he believes it is the best furnace in use, but for periods of more than two hours it has been known to give trouble by slagging up.

The New Steel Works of Peine.—These new works, specially designed for the requirements of the basic process, are ultimately to embrace six converters, although only three have been erected up to the present time. To serve these six converters, two travelling cranes on Trappen's system are to be provided on the same line of rails. Each crane is, however, available for each converter. The ingot moulds stand on the same side of the line of crane rails as the converter, and in sheds adjoining the converter on each end, but built quite independently of the converter house. The hydraulic crane need not, therefore, be turned for the purpose of serving the ingots, an arrangement which saves trouble and time. As soon as the ladle is filled, the crane steams off to any desired part of the ingot foundry, and discharges its load into the moulds. The work of the converter hands, as well as the foundry men, is not so much interfered with by the heat as in ordinary practice, since the converters and ingots are removed from each other, and each has only its own heat to bear, which is, moreover, reduced as much as possible by large and lofty buildings. Parallel to the six converters, six cupolas of the largest size are placed at such a height that each converter can be charged from three cupolas. Between cupolas and converters trucks run on standard gauge permanent way for the removal of the slag and for the transport of converter parts. A plan of the Bessemer department of these works, for which we are indebted to *Engineering* of October 6th, 1882, is attached hereto.



A New Ladle Crane for Bessemer Works.—Mr. Alfred Trappen, Wetter-on-the-Ruhr (*Engineering*, October 6, 1882), describes a new ladle crane for Bessemer Works, which he has designed for the Bessemer process, modified to meet the requirements of basic steel-making, as it is carried on at the works of Hörde and Peine in Germany. The crane, which is available for charges up to ten tons, is carried on a strong six-wheeled truck, and is fitted with a fixed plunger, movable cylinder, and wrought iron ladle fork, prolonged backwards to carry the necessary balance weight. The ladle is, as usual, movable in a radial direction. The arrangements for accomplishing this, as well as tilting the ladle, are of the usual type. The crane has a radius of 7 feet 4½ inches, and a lift of 3 feet 3½ inches, the ladle a radial movement of 3 feet 3 inches, principally for the purpose of accommodating two rows of ingot moulds.

A double cylinder reversible engine is connected to the middle axle of the truck by a pair of gear and bevel wheels, a coupling being provided to disconnect the engine from the truck. This same engine works pumps on its continued piston rods up to twenty atmospheres, the suction and delivery valves of which are placed directly over a water tank of suitable dimensions. On the platform are conveniently situated the reversing lever and the working gear for the hydraulic crane, and the whole is protected from flying sparks and slag by a corrugated roof. A self-contained powerful steam pump is provided to feed the boiler, and also to make up the loss through leakage in the hydraulic crane during the process of casting. To do this by means of the main pumps would always necessitate the engine being thrown out of gear with the truck, which is not desirable.

The boiler is of 10 horse-power, of the water-tube type, constructed for a working pressure of 90 lbs. The driver, as well as all parts of the machinery, are sufficiently protected against flying sparks by sheet-iron partitions and roofs. The six-wheeled truck with steel axles and steel wheels has been made exceptionally heavy, partly to give ample stability for the high loads put upon it, partly to place the centre of gravity of the whole structure as low as possible, giving stability and safety in working.

The first of these hydraulic travelling cranes has now been in regular work at Hörde for over six months, and since the carrying out of a few slight alterations, suggested soon after starting, no interruptions in the regular work have taken place, while the converter and ingot foundry hands are enjoying greatly improved conditions of working. The capacity of the crane is from 40 to 45 charges of 10 tons during a double shift, which are taken up and cast into the ingot moulds by one crane.

Determination of Carbonic Oxide in Air (*Zeitschrift für Analytische Chemie*, vol. xx. part 4. I. V. Foder).—The author allows moderately diluted blood to remain in contact with the air in question in a 10 to 12 litre bottle, or he passes 10 to 12 litres of the air through the blood, and then shakes it up in a test-tube with ammonium sulphide. Unmodified blood appears violet by transmitted light, whilst that which has absorbed carbonic oxide is coloured red. For the quantitative determination of the carbonic oxide absorbed by blood, the latter is put in a small flask, through the perforated stopper of which are passed two tubes. The one which reaches to the bottom serves to introduce air washed by a passage through palladious chloride. The other conducts the air issuing from the flask into two washing bottles, one of which contains a solution of lead acetate, and the other dilute sulphuric acid. From the washing bottles the air passes into two U tubes containing palladious chloride. The flask is then set on a water-bath, and the blood kept for a quarter of an hour to half an hour at 90° to 96°. Meanwhile an exceedingly slow current of air is aspirated through the flask, which is frequently shaken. As soon as the colour of the blood begins to change, the carbonic oxide-haemoglobine is split up, the carbonic oxide is set free, and a black precipitate of palladium appears on the surface of the solution of palladious chloride. This is separated, washed, dissolved in *aqua regia*, and the solution is treated with a standard solution of potassium iodide (1·486 grm. KI per litre) till a filtered portion no longer gives any turbidity with a drop of the potassium iodide. In this manner its quantity, and consequently the quantity of the carbonic oxide, can be calculated. Each c.c. of the potassium iodide represents 0·1 c.c. carbonic oxide.

A Novelty in Foundry Practice.—Herr G. Ahlemeyer describes in *Glaser's Annalen* a new system of melting iron, and at the same time incorporating in it scrap, wrought iron, &c. The inventor is Herr Ibruegger, a well-known engineer, who has built one furnace at the Michelbacher Huette, at Michelbach, Hesse-Nassau, and another at the works of Julius Meyer & Co., at Norden. The cupola is supplied with blast through two sets of tuyeres, one above the other, there being eighteen in each set. The tuyeres, or ports, which have the form of a vertical slit, are directly connected with a circular tuyere ring. The particular feature of the cupola is, that the bottom is a slightly inverted arch, which is pierced by two openings, through which both blast, or rather imperfectly consumed gases of combustion, and the fluid iron can flow. Below it is a small chamber in which the iron collects. It is heated by the gases forced downward from the cupola above, which are supplied with the necessary air for combustion by a special tuyere leading from the main blast-pipe. This chamber at the same time serves for preheating scrap, &c., which need only be pushed into the bath for dissolving it.

Of course, it is well known that considerable quantities of scrap can be used by directly charging in any ordinary cupola; but it is claimed that in this case there are economy of fuel and a greater facility in making sharp strong castings and a purer metal. The best iron for this purpose is said to be inferior pig, like No. 3 Middlesbrough, holding considerable silicon and little manganese. To it from 40 to 50 per cent. of scrap, &c., may be added. The total consumption of fuel is stated to be 10 per cent. of the weight of the product.

A Producer's Classification of Iron and Steel.—The classification of iron and steel proposed by the German Railway Union as a basis for the supply of railway material having given rise to considerable discussion among the producers of such material, a commission for the purpose of drawing up a revised scheme was formed by the Society of German Ironmasters; and at a general meeting held at Düsseldorf, on May 28th and 29th, 1881, was adopted after discussion. The commission deprecated the practice of using the contraction of the fractured area alone as a principal measure of the toughness of the material, and considered that evidence of greater practical value as to this property is to be obtained from the results of the falling weight and bending tests combined. After some preliminary instructions in the method of preparing test pieces, the classification of the tests is given as follows:—

I. TESTS WITH UNDIVIDED OBJECTS.

a. Cold Tests. 1. External inspection; 2. Hammering; 3. Falling weight; 4. Direct loading. *b.* Hot tests.

II. TESTS WITH SEPARATED PIECES.

a. Cold. 1. Bending; 2. Punching; 3. Breaking; 4. Tensile. *b.* Hot. 1. Bending; 2. Punching; 3. Forging; 4. Welding.

For steel rails, the commission propose that falling tests should be applied to rail pieces that have not been either notched or bored, and whose ends do not project more than half a metre beyond the bearings. The falling heights of a weight of 600 kilos., fixed for rails of different sections, are—

a.	Weighing above	30	kilos. per metre	and about	130	millims. high,	5	metres.
b.	,,	27½–30	,,	,,	120	,,	3·25	,,
c.	,,	23 –27	,,	,,	110	,,	2·5	,,
d.	,,	20 –24	,,	,,	100	,,	2	,,

The test piece, one metre long between the points of support, in each case to receive two blows without fracture.

As a loading test, the commission propose that for the different sections and weights given above, the weights which should be supported without producing more than half a millim. permanent deflection are:—

a. 17,500 kilos.; *b.* 13,500 kilos.; *c.* 11,500 kilos.; *d.* 10,000 kilos.

The bending test proposed is: a length of rail, one metre between the points of support, to bend to 50 millims. over both head and foot without fracture.

Under the assumption that either the contraction of area or the longitudinal extension, but not both, may be used in judging the quality of the material, the commission recommend the following tensile tests with prepared test pieces:—

Bars of 200 millims. long and 20 millims. diameter shall bear a minimum load of 50 kilos. per sq. millim., with a contraction of 20 per cent., or an elongation of 12 per cent.

As regards further conditions in contracts for supplying rails, the commission remark as follows:—

1. As limits of toleration in weight, 3 per cent. above and 2 per cent. below the normal amount, and of the excess weight only 2 per cent. should be paid for.
2. As regards maximum length, 9 metres, beyond which very few rolling mills are capable of working, while for greater lengths the risk of damage in transport is greatly increased.
3. About 5 per cent. of the rails shorter than the standard length to be received.
4. The guarantee for rails is fixed at five years, commencing on the 1st of January next following the date of delivery.
5. Rails worn out in regular traffic not to be replaced under the guarantee. The guarantee on rails replaced to terminate at the same date as that on the original contract.

The number of rails reserved for testing not to exceed one-half per cent. of the whole amount.

Tests are also specified for tyres, axles, sleepers, fish-joints and bearing-plates, constructive material, and plates, &c., in iron and steel. A full translation of the proposed classification appears in the *Abstracts of Papers in Foreign Transactions*, published by the Institution of Civil Engineers.

The Basic Lining of Converters.—V. de Mattei, in the *Genie Civil* of June 1st, 1882, describes the mode of lining basic converters as practised at Rothe Erde, near Aix-la-Chapelle. The dolomite is roughly broken and burnt in a cupola of nearly cylindrical form with about one-fourth its weight of coke; after picking out residues of coke the burnt stone, which must have a glazed surface, is ground in a pug-mill with about 8 per cent. boiled tar. The latter is run out of a measuring vessel which is connected with a larger reservoir in which the tar can be heated by means of a steam worm.

The rollers of the mill have a weight of 5 tons, their faces consist of a strong ring of cast steel; 80 kilos. dolomite can be mixed in three minutes. A twenty horse-power engine suffices for the mill and the cupola fan. The converter bottoms are made by ramming the mixture, by means of heated stamps, into iron moulds, in which, corresponding to the air channels, pins are inserted. They are then conveyed into the flue of a heating oven, and there baked for 18 to 20 days. The throat of the converter is lined with appropriately shaped basic lumps which are made in an analogous manner, but require only 3 to 4 days' baking. The upper part of the shell, next to the basic ring around the mouth of the converter, is formed of silicious material, while the lower part of the lining is again basic. The loose bottom is put in from below, and the joint between it and the lining of the shell is filled with some of the plastic mixture. Each bottom lasts 18 to 20 charges, the lining of the shell about 60.

The dolomite should contain not more than 3 per cent. silica, and 4 per cent. alumina and iron oxide.

It seems that basic bricks, made in accordance with Mr. Thomas's original patent, by directly burning bricks formed from raw dolomite, are no longer used.

Mortar for Refractory Brickwork.—*Stahl und Eisen*, No. 9, 1882, contains an article of F. Lürmann, in which he states that ordinary mortar, cement, slag, and other fusible substances, mixed with sand or ground firebrick, have been successfully substituted for fireclay, or other fireproof material, as a mortar for firebricks. The joints should be made as thin as possible. The structures before being fired will have the advantage of greater stability, while on firing the whole will gradually unite into one solid mass, free from loose and open joints, and of greater strength than is attained with fireclay. The bricks used should be not larger than the ordinary size, as big lumps usually are not thoroughly burnt, and therefore are subject to gradual and irregular contraction.

On the Difference of the Volume of Metals in the Solid and Liquid State (*Zeitschrift D. Ing.* 1882, p. 414, from *Proceedings of the München Academy*).—Experiments by Messrs. T. Nies and A. Winkelmann lead to the conclusion, that as a rule metals expand at the moment of solidifying. Tin, after being carefully heated to its melting point (440° F.), was found to float on melted tin, and even to rise again to the surface when pushed down. By weighting the solid metal with pieces of copper till complete immersion took place, it could be calculated that the proportion of the volumes of the liquid and solid metal at the melting point was as 1 : 1·007. Lead and cadmium did not give any decisive result; zinc, however, floated like tin, the proportion of the specific volumes being as 1 : 1·002. The phenomenon is most marked in the case of bismuth, the liquid metal being above three per cent. heavier than the solid. As cadmium, copper, and iron behave similarly, and altogether six metals out of eight which were examined expanded on cooling, this property must be considered the rule for metals; it is noticeable that those which solidify in the crystalline form expand in a more marked degree than the others.

The Theory of Rolling.—Herr E. Blass contributes to *Stahl und Eisen*, 1882, No. 7, a mathematical study on the theory of rolling, founded mainly on the assumption—which appears to be fully justified by the author's experiments and by well-known phenomena in the compression and rolling of metals and other bodies—that within a compressed substance conoids or wedge-shaped bodies are developed, the bases of which coincide with the surfaces of contact of the compressing body, and which themselves, at the moment of contact, do not partake of the deformation. In the case of rigid bodies an actual isolation of the conoids takes place; in the case of plastic bodies, a flow of those particles of the material which are in close proximity to the conoid. The subject is treated under the following heads:—1. Spreading. 2. Acceleration. 3. Pressure on the rolls; influence of elasticity. 4. Force required to draw the block through the rolls. 5. The work performed in rolling. 6. On the maximum reduction per pass. 7. Heat produced in rolling.

Utilisation of Slag from the Basic Steel Process in Agriculture (*Stahl und Eisen*, July 1882).—A few investigations in this direction have been made at the instance of a Westphalian steelworks. A slag containing 19·33 per cent. P_2O_5 was treated with different quantities of sulphuric acid of 66 per cent. With reasonably low quantities of the latter only a small proportion of the phosphoric acid was converted into its soluble, viz., its most active modification, as appears from the following analyses:—

Constituents.	P_2O_5 Total.	P_2O_5 Soluble in Water.	P_2O_5 Soluble in Citrate of Ammonia.	P_2O_5 Soluble in Hydrochloric Acid.
Original Slag	19·33	None.	10·94	8·39
Slag with 70 per cent. Sulphuric Acid . . .	12·13	1·15	9·35	1·53
Do. 100 do. do. . .	8·07	4·61	2·75	·71
Do. 100 do. do., examined three months after mixing	8·07	·63	6·56	·88

More than one-half of the P_2O_5 of the original slag being soluble in citrate of ammonia, viz., in a form in which it is nearly equally well assimilated by plants as when soluble in water, it seems most reasonable to employ the slag without any chemical treatment in a finely powdered state. In order to render harmless the sulphides present, it is recommended either to mix the powder with stable manure, or to spread it in autumn, so that the oxidation of the sulphides may be finished when the manure comes in contact with the seed.

In trials on a small scale it was found that mixtures of the same river sand with—

1. Potash, nitrate of soda, and guano-superphosphate;
2. Superphosphate prepared from slag;
3. Slag powder;

gave equally good results when applied to summer-rye and vetches.

To Prevent the Oxidation of Iron Wire in Re-heating (*Le Fer*, 1882, No. 32), Herr Schulte, of Bochum, fills the receptacles containing the wire with nitrogen. This gas is prepared from air by passing it through a heated tube containing, first, a layer of coke and then of oxide of copper or of iron. A mixture of nitrogen and carbonic acid is so obtained in the first instance, which, in passing a coke scrubber moistened with lime-water or caustic soda, is freed from its CO_2 and then collected in a gas-holder. From this the different vessels containing the wire are supplied; the gas, however, before entering the vessels is freed from moisture in a drying apparatus containing quicklime, which apparatus is connected to the heating pots by means of flexible tubes. The covers of the heating vessels rest in grooves filled with fusible metallic alloys or other fusible bodies, as potassium chloride or nitrite, so that a perfectly air-tight joint is obtained. Two tubes are attached to the lid, the one reaching the bottom of the vessel, for the admission of the gas, the other, opening just inside the vessel, serving as outlet for the air. In starting, a quantity of nitrogen equal to about three to five times the contents of the vessel is passed through it, while the fusible contents of the grooves are melting; then the taps of inlet and outlet are closed, and the heating is proceeded with in the usual manner. After the pots are taken out the nitrogen supply is turned on again to allow for the contraction of the residual gas which takes place in cooling. The object of excluding the air is attained so perfectly that not only wire which has been charged with a clean surface is taken out in the same condition, but wire put in with a blue surface comes out perfectly white.

B.—STATISTICS, &c.

Exports, &c.—The *Montan Zeitung* publishes the following table of the exports of steel rails from Germany in each year since 1860:—

	Tons.		Tons.
1860	1,270	1871	41,800
1861	6,780	1872	70,700
1862	3,730	1873	70,000
1863	4,040	1874	84,900
1864	5,350	1875	122,000
1865	2,400	1876	133,000
1866	2,090	1877	225,000
1867	4,300	1878	207,000
1868	28,600	1879	164,000
1869	37,100	1880	230,204
1870	36,000	1881	350,709

Russia was formerly the principal consumer of German rails, but the chief customer is now Holland, and large quantities have gone to the United States, Spain, Switzerland, and Belgium.

The Berlin Mercantile Association having been consulted as to the character and extent of the competition of English and Swedish pig iron with the iron of Westphalia, and as to the present prices of foreign pig iron in the German markets, has drawn up the following table, showing the quotations for pig iron in marks per 100 kilos. free at Berlin, from the 1st May 1881 to the 1st April 1882:—

	Scotch Iron.		English Iron.		German Iron.	
	Coltness.	Langloan.	I.	II.	I.	II.
May 1, 1881	8·10	8·10	6·60	6·20	8·20	7·80
June 14, 1881	8·10	8·16	6·40	6·10	8·20	7·80
July 22, 1881	8·10	8·10	6·54	6·14	...	...
August 13, 1881	7·75	7·75	6·32	5·92	8·30	7·80
Sept. 27, 1881	8·17	8·17	6·74	6·32	8·80	8·60
Nov. 15, 1881	8·16	8·16	6·72	6·30	8·70	8·50
Dec. 6, 1881	8·65	8·60	6·88	6·44	9·05	8·85
January 3, 1882	8·60	8·54	6·84	6·40	9·00	8·80
March 7, 1882	8·10	8·10	6·60	6·20	8·20	7·80

As to Swedish iron, the report states that it has never very seriously threatened Germany's products. The English iron is still largely consumed on account of its cheapness. The association strongly recommends the adoption of cheaper railway tariffs for the carriage of pig iron from the Rhenish iron districts to Berlin, in order that the competition against England may be made more successful.

Production of Pig Iron.—The German Ironmasters' Association gives the following official particulars relative to the production of pig iron during the first six months of 1882:—

	Tons.
Forge pig	920,655
Spiegel	74,944
Bessemer pig	354,582
Foundry pig	131,582
	1,481,763
Corresponding period, 1881	1,323,720

The blast furnaces were employed at the end of July as under:—

District.	Description of Iron.			
	Forge.	Spiegel.	Bessemer.	Foundry.
North-West (Rhine Province and Westphalia)	37	15	16	8
Eastern (Silesia)	13	...	2	8
Centre (Saxony, Thuringia)	1	...	1	1
Northern (Saxony, Brandenburg, Hanover)	1	...	1	1
Southern (Bavaria, Wurtemburg, Luxemburg, Hesse, and Nassau)	12	1	1	Thos. 1
South-Western (Sarre and Lorraine)	9	1	1	2
	73	17	22	28

There were thus 140 blast furnaces in operation in Germany, half of them producing forge pig.

The *Wochenschrift des Vereins Deutscher Ingenieure* (Berlin, September 23) publishes the following statistics of the mines and iron works of the Grand Duchy of Hesse during 1881—

	Number of Works.	Tons.
Lignite	9	30,738
Iron ore	18	133,261
Manganese	1	1,071
Charcoal pig	1	1,477
Coke pig	2	33,420
Foundries	13	4,946
Rolling mills	1	86

Iron and Coal in Bavaria.—The production of iron, coal, &c., in 1881 has been as under:—

	Production in Metric Tons.	Value in Marks.
Coal and pitch coal	494,287	4,304,361
Brown coal	16,642	62,502
Iron ore	75,580	360,776
Manganese ore	70	280
Pig iron	37,280	1,920,070
Castings, 1st fusion	1,848	324,216
Do., 2d fusion	28,928	5,700,245
Wrought iron	.61,811	9,025,266
Sheet iron	3,652	834,229
Iron wire	3,355	579,886
Steel	2,113	318,247

Coal.—According to the *Würtemberger Gewerbeblatt,* the coal production of Germany has so enormously increased within the last two decades that there is reason to fear an exhaustion of the beds at no very distant date. While the production of England in that period has risen from 85·4 million tons to 149·3 millions, that of France from 8·3 millions to 19·4 millions, that of Belgium from 9·6 millions to 16·9 millions, the German yield of coal has increased from 12·3 millions to 59·9 millions—a proportion reached approximately only by North America, which shows a rise in production from 15·2 million to 70·3 million tons. Considering that the coalfields of Belgium comprise about 900 square miles, those of France 1800, those of Germany 3600, those of England 9000; and comparing with these the vast coalfields of the East Indies, 35,500 square miles; North America, 193,870 square miles; and China, over 200,000 square miles, the question of so improving means of international traffic that a low cost of transport may render possible a continuation of industrial work on European soil even with foreign coal, becomes, in the opinion of the writer referred to, most important.

RUSSIA.

A.—METALLURGICAL TECHNOLOGY.

The Alexandrowsky Steel Works (*Engineering*, October 27th, 1882).—These works were completed at the end of 1877, commenced business in March 1879, and since that time have been in continuous operation. The products are steel rails for the Government lines, and projectiles and guns of cast steel, these latter being made according to the Terre-Noire process. The plant comprises seven melting and six preparatory heating furnaces on the Siemens-Martin principle, which are arranged in a single line about 350 feet long. The heating and melting furnaces alternate with each other. Six of the melting furnaces are of seven-tons capacity, while the seventh takes a nine-ton charge. The latter is a little over 3 feet larger than the smaller ones, and has two openings instead of only one on the working side. The gas-producers are placed in a line parallel to the furnaces, there being four to a melting and three to a heating furnace, and each pair of furnaces has its own chimney. The capacity of the four regenerator chambers under each melting furnace is 1539 cubic feet; and as the consumption of coal is about 9 tons daily per furnace, the capacity per ton of coal per day is about 170 cubic feet. The hearth bottoms of the melting furnaces, which are carried upon 2-in. cast iron plates, are made of a lower layer of Dinas bricks, 2½ in., covered by 7 in. of a mass formed of 42·5 per cent. of clean sand from Lake Ladoga, 42·5 per cent. of burnt quartz, and 15 per cent. of Russian fireclay; the sides and roofs are of Dinas bricks. The average working life of the furnace is 232 charges, the highest attained being 280. The roof requires partial renewal after about 150 charges.

Specific Gravity of Liquid Steel.—An attempt has been made to determine the specific gravity of liquid steel according to a method proposed by Mr. Petruscherosky. In the method referred to, a porcelain tube, open at both ends, was connected at one end with a forcing pump and a manometer, while the other end was immersed in liquid steel to a given depth. On pumping, bubbles appeared at the latter end, and the indication of the manometer at that moment, compared with the depth of the immersion, served for a determination of the relative density of the steel and the liquid (naphtha) used in the manometer. The specific gravity of liquid steel was thus found to be 8·05, being greater than that of solid steel.

Manufacture of Ferro-Manganese.—The manufacture of ferromanganese has been undertaken at the Demidoff Works. The product is said to contain from 60 to 70 per cent. of manganese, but owing to the great distance of the works from St. Petersburg, the works cannot compete in this respect with the imported article, notwithstanding that the empire contains large deposits of rich manganese ores.*

The Basic Process in Russia.—Mr. Sergius Kern communicates some information of interest respecting the working of the basic Bessemer process in Russia. It seems that the process has been commenced at the Alexandrowsky Works, near St. Petersburg, with the Siemens furnace, instead of the Bessemer converter.† As yet, however, it has been carried on only to a very limited extent, the total quantity of basic steel made during the financial year 1881–82 having been 134 tons. The pig iron used contains 1·5 per cent. of phosphorus, while the content of phosphorus in the steel produced was only 0·037 to 0·042 per cent. The basic process is also now carried on at the works of New Praga.

Steel Wire.—The recent increase of the duty on steel wire has led to the erection of some new mills for its manufacture in Russia. At the works of Messrs. Mertin & Co., St. Petersburg, steel wire is now being produced regularly from slabs or blooms manufactured by the basic process, and tests of this wire are said to have yielded very satisfactory results.

Steel Ordnance.—The largest steel gun manufactured in Russia up to the present time was shown at the Moscow Exhibition during the autumn of 1882. It was made at the Obouchoff Steel Works from crucible steel. The calibre of the gun is 12 inches, its weight 50 tons, and its cost 80,000 roubles. The weight of the projectile used is 810 lbs. and that of the charge 313 lbs.

Steel Shipbuilding in Russia.—Attention has recently been given by several of the chief steel-works in Russia to the manufacture of steel plates suitable for shipbuilding. At the Moscow Exhibition this year, the Kolpino Works, near Petersburg, exhibited a steam launch made with 18 steel plates, having a length of 37 feet 9 inches, and worked by a compound engine of 50 horse-power. The largest steel plate shown at this exhibition was 34 feet long, 7 feet wide, and 1 inch in thickness.

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* See *Journal*, 1877, p. 64, and 1881, p. 713.

† A description of the manufacture of steel at Creusôt with the Siemens furnace will be found at p. 771, *ante*.

Russian Steel Rails.—The first steel rails turned out at the Alexandrowsky Works contained 0·15 to 0·20 per cent. of phosphorus, carbon 0·25 per cent., and manganese 0·45 per cent. As rails of this composition would not stand the extreme cold of the Russian winter, the proportion of iron rails and pig metal was reduced, that of steel scrap being correspondingly increased. The amended charges were made as follows: Pig iron, 15 per cent.; steel scrap, 66 per cent.; iron rails, 15 per cent.; spiegeleisen, 1 per cent.; and ferro-manganese, 3 per cent.; thus giving a total product with 0·08 to 0·10 per cent. of phosphorus, 0·3 to 0·4 per cent. of carbon, 0·8 to 0·9 per cent. of manganese, and only traces of silicon.

B.—STATISTICS, &c.

Iron Ore.—The production of iron ore in Russia during 1880 is stated in the Russian official *Journal* to have been 62,493,424 poods (1,013,200 tons). In 1879 the output was 980,257 tons, and in 1878, 897,098 tons, so that the production of 1880 was considerably over that of either of the two previous years. The number of iron-ore mines and workings in operation during 1880 was 956, being an increase of 28 on the previous year, while 1124 were altogether idle, being 172 less than in 1879. Of manganese ores, 614,549 tons were raised in Russia in 1880.

Pig Iron.—The production of pig iron in Russia during 1880 was 27,375,000 poods (440,000 tons). This is an increase of 12,000 tons on the production of 1879, and of 32,000 tons on that of 1878. Dividing the production of pig iron into the total output of iron ores, it would appear as if the average consumption of ore in Russia per ton of iron made was 2·3 tons, which would represent a higher average content of iron in the ores than that generally found in Europe. Dealing with the corresponding statistics available for other iron-making countries, we find the average consumption of ore per ton of iron produced to be as under:—

Country.	Production of Pig Iron.	Consumption of Ore.	Average Consumption of Ore per ton of Pig produced.
	Tons.	Tons.	Tons.
France	1,388,219	4,375,000	3·15
Germany	2,133,015	6,802,000	3·18
Austria	379,639	618,963*	1·63
Sweden	399,000	762,930	1·91
United Kingdom	8,377,364	20,249,263	2·41
United States	3,781,000	8,804,000	2·32

The number of blast furnaces working in Russia during 1880 was 206, so that each blast furnace produced an annual average of 2135 tons of pig iron, as compared with an annual average of 14,763 tons per furnace in the United Kingdom, 10,584 tons per furnace in Germany, and 4,980 tons per furnace in Austria.

Of the 440,000 tons of pig iron produced in Russia in 1880, only 28,000 tons were made with mineral fuel, the remainder having been produced exclusively with charcoal.

In addition to the quantity of pig iron already stated, 3,200,000 poods (51,400 tons) of castings were turned out in Russia during 1880.

Finished Iron.—The production of wrought iron in Russia during 1880 has been as under :—

	Poods.		Tons.
Merchant iron	12,958,044	=	208,254
Iron rails	313,364	=	5,036
Sheets and plates	4,559,123	=	73,142
Iron wire	203,057	=	3,263
Totals	18,033,588	=	292,695

These totals show an increase on the corresponding figures for any previous year, the aggregate make of wrought iron in 1879 having been 274,866 tons, and in 1878, 267,710 tons. It will be observed that the iron rail trade has fallen to a very small figure, the use of iron rails having almost entirely ceased in the Russian dominions.

The total number of puddling furnaces at work in Russia during 1880 was 464, being an increase of twenty-two on the number at work in 1879. The average annual production of finished iron per puddling furnace, assuming that puddling furnaces alone were used, would thus come out as 630 tons, but much of the wrought iron manufactured in Russia is obtained by the bloomery process. The official statistics show that there were no less than 659 bloomeries at work in 1880; and as there is no record of the quantity of iron made by these, it becomes quite impossible to compute the average yield of the puddling furnaces over the year. The tendency of the bloomery process is towards further decline, the number of such forges at work in 1880 having been twelve less than in the previous year, notwithstanding that the actual output of finished iron was larger in the former year than in the latter.

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* This is the ore raised in Austria only; but a considerable quantity is now also imported from Hungary, of which particulars are not available.

Steel.—The production of Bessemer and Siemens-Martin steel in Russia during 1880 was 18,343,580 poods = 294,800 tons. This is an increase of 92,000 tons on the production of the previous year, when the output of such steel reached an aggregate of 202,000 tons, being, in its turn, an increase of 140,314 tons, or 220 per cent. on the production of 1878. These figures show the remarkable strides that the steel manufacture has made in Russia within the last few years.

Of steel rails, the production in Russia during 1880 was 12,294,548 poods = 187,590 tons, so that only 97,300 tons of Bessemer and Siemens-Martin steel were left to be worked up into plates, &c. As the statistics of the finished iron manufacture show, the great bulk of the sheets and plates used in Russia is still made of wrought iron. The Russian steel-works have within the last two years come very near to the point of supplying the requirements of the country in respect of railway material, the total imports of steel rails in 1880 having been only 34,000 tons against 152,504 tons in 1878, showing within two years a decline of imports to the extent of 118,504 tons, although the consumption in the two years was not greatly different, having been 206,931 tons in 1878 against 231,500 tons in 1880. There are now 24 Bessemer converters and 62 open-hearth furnaces in Russia.

Crucible, Blister, and Puddled Steel.—The total output of blister and puddled steel in Russia in 1880 was 417,718 poods, and of crucible steel, 237,218 poods.

Coal and Lignite.—The production of fuel in Russia during 1880 was as under:—

Coal	168,925,405 poods
Anthracite	29,541,217 ,,
Lignite	1,587,381 ,,
Total	200,054,003 poods

equal to a total output of 3,214,895 tons, against a total of 00 tons in 1879.

Imports of Iron and Steel from Different Countries.—The imports of coal, iron, and steel into Russia from other countries during 1880 have been as under :—

Coal.

From—	Poods.		Tons.
England	83,688,220	=	1,344,989
Germany	21,373,015	=	343,464
Austria	7,832,700	=	125,871
France	951,360	=	15,288
Turkey	66,453	=	1,067
Belgium	96,897	=	1,557
Holland	15.000	=	241
Denmark	19,292	=	310
Roumania	94,412	=	1,517

Pig Iron.

From—	Poods.		Tons.
England	9,731,582	=	156,386
Germany	3,919,010	=	62,978
Belgium	291,814	=	4,689
Sweden	191,139	=	3,071
Austria	776,866	=	12,484
France	24,875	=	400
Turkey	88,953	=	1,429
United States	3,410	=	55

Wrought Iron.

From—	Poods.		Tons.
England	5,150,788	=	82,772
Germany	4,194,989	=	67,413
Belgium	2,267,407	=	36,437
Austria	227,279	=	3,652
Sweden	69,915	=	1,123
France	51,427	=	826
Roumania	2,615	=	42

Steel and Steel Rails.

From—	Poods.		Tons.
England	1,587,839	=	25,516
Belgium	409,239	=	6,576
Germany	1,650,763	=	26,528
Turkey	88,639	=	1,424
Sweden	789	=	14
Austria	182,109	=	2,926
France	96,689	=	1,554

Prices of Iron and Steel in 1880 (*per pood, in copecks*).—*Nishni-Novgorod Fair.*—Pig iron, 75; round and square merchant iron, 146–240; flat iron, 165–170; hoop iron, 174–185; iron rails, 200; boiler iron, 240–350; iron sheets, 250–335; blister steel, 200–440; castings (pig iron), 135–190; nails (iron), 300–500; horse-shoe nails, 900; simple iron forgings, 200–300; tin plates, 400–600.

Poland (*per pood, in copecks*).—Castings (pig iron), 140–400; flat iron (bloomery), 194–220; iron plates (puddled), 250; steel rails, 170–200; tyres, 320.

Finland (*per centner, in marks*).—Pig iron, 5·25; Bloomery iron, 7; flat iron, 13; Siemens-Martin plates, 20; sheet iron, 18; simple iron forgings, 25.

SWEDEN.

New Swedish Minerals.—Manganbrucite and talktriplite, two new minerals from Wermland, Sweden, have recently been described by Professor D. J. Igelström. *Manganbrucite* occurs at the manganese mines of the Jacobsberg, together with a number of other minerals. It is found in granular form of the size of hemp-seed, in hausmannite ore, consisting of hausmannite more or less thickly imbedded in calcite. Its colour varies from honey yellow to brownish red, and was perhaps originally nearly colourless. It is translucent in thin splinters, and an analysis, after deducting a very little silica and calcite, gave the following result:—

MgO	MnO	H_2O
57·81	14·16	28·00=99·97

The *Talktriplite* is from Horrsjöberg in Wermland, where it is found with various phosphates. It occurs in grains of the size of a pin's head; its colour varies from yellow to yellowish red; it is transparent, and an analysis of 0·85 grain of the mineral mixed with matrix (0.585 insoluble in hydrochloric acid) shows it to contain:—

P_2O_5	FeO	MnO	CaO	MgO
32·82	76·72	14·86	14·91	17·42=96·13

It contains some fluorine, which, however, was not determined. The calculated formula is $(Fe, Mn, Mg, Ca)_4 P_2O_9 + CaF_2$, but the analysis is too imperfect to determine the composition with certainty. Professor Igelström suggests that perhaps the true formula is $R_3P_2O_8 + RF_2$, and then the mineral would be essentially a triplite containing lime and magnesia. The name given has reference to this supposition.

Iron Ores of Sweden.—*Iron* of July 28, 1882, contains a translation of a report on the iron ores of Sweden by Professor R. Åkerman. The author deals with both mountain and bog ores. The present memoir does not add much to what has already appeared on the same subject,* but it is an admirable epitome of the available knowledge concerning these rather remarkable deposits. Speaking of the calcination of the magnetic ores, which is rendered necessary by their combination with metallic sulphides, the author states that the best gas calcining kilns in use in Sweden are those constructed by Westman, of which the first was erected in 1851; on which construction he has, however, improved during later years. In this calcining kiln the temperature may be kept so high that the most refractory ores become soft, and by their help many ores, which could not formerly be used on account of the sulphur they contain, can now be utilised. These furnaces have, notwithstanding the larger quantity of gas which they consume, more and more replaced the older gas calcining kilns, in which the same temperature cannot be kept without the ore running together in such a way that it cannot be got out without the greatest difficulty. Some of the ores found in Sweden are very rich in titanium, which does not appear to be in general a desirable ingredient, as the reduction of such ores is rendered difficult by the presence of that body, and the consumption of charcoal in smelting ores rich in titanium is consequently very great. Among such ores, that at Taberg, in Jönköpings län, deserves special notice, as it is in several respects different from the ores common elsewhere in Sweden. It consists of a mixture of olivine, partly decomposed to serpentine, and grains of titanate of iron covered on the surface with silicate of iron and felspar. This mixture is so intimate that the three ingredients can only with difficulty be distinguished by the naked eye, and it has in consequence also been found impossible to increase the contents of iron in this ore by a dressing process. At Taberg a whole hill has been formed of such ore about 400 feet in height and 9000 feet in length, but the contents of iron is not greater than 30 per cent.; and further, it contains the large quantity of 6 per cent. of titanic acid. There is in some Swedish ores also found a small quantity of bitumen; as, for instance, in the ores of Gök and Torf in Norberg, and Wiker in Nora; and in others, as that of Uddevalla in Norberg, a little graphite.

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* *Journal of the Iron and Steel Institute*, 1874, p. 310; 1876, p. 228; 1880, p. 415.

Steel Castings.—The production of steel castings is making progress in Sweden. They are now being manufactured at several works, both by the Bessemer and by the Siemens-Martin process. Up to the present time, however, the Terre-Noire process is carried on only at the works of Bofors, where it continues to be applied to the production of steel ordnance.

Manufacture of Soft Steel.—At four different works in Sweden Siemens-Martin furnaces have been erected during the past year for the purpose of producing soft ingot iron, partly for horse-shoe nails, wire, &c., and partly for nails which can be riveted. Common Swedish scrap iron is employed for ordinary nails and bolts, but great care is exercised in the selection of both the pig and the wrought iron used for the production of Siemens-Martin ingot iron, the object in view being that of obtaining a soft product which can easily be rolled, although little or no ferro-manganese is used in its manufacture. In this manufacture the very purest materials only are used, and at some works such attention is paid to this requirement that ordinary scrap, if at all rusty, is rejected. The charges average from three to four tons, the maximum weight of the charge being about five tons. Wood and peat are almost exclusively used as fuel.

Caspersson's Converter-Ladle.—Seven of the Bessemer steel-works in Sweden have now adopted the Caspersson converter-ladle, with results which, in every case, are described as satisfactory. Professor Åkerman states that the average product obtained in the manufacture of soft ingot iron with this ladle is now 89 per cent. to 90 per cent., whereas some years ago it did not exceed 85 per cent. The ingots produced are, moreover, found to be much denser than they were before the introduction of the converter-ladle.

Utilisation of the Waste Heat of Swedish Blast-Furnaces.—*Jern Kontoret's Annaler* describes a method recently introduced at some of the ironworks of Sweden, the introduction of which is due to Mr. Lindberg, whereby the charcoal used in the manufacture of iron is thoroughly dried by the otherwise waste heat of the pig iron and slag as it comes from the blast-furnace.

Effect of Heat upon Bessemer Steel Ingots.—*Jern Kontoret's Annaler* for 1882 contains an interesting memoir by C. A. Caspersson and Professor Åkerman, relative to the influence of heat during the Bessemer process upon the properties of the ingots.*

A New Explosive.—A consular report from Sweden, issued by the Foreign Office, gives a description of a new explosive called sebastine, which, it is said, has competed most favourably with dynamite. Sebastine appears to be an explosive based upon nitro-glycerine, but safer to handle than the ordinary dynamite, while more powerful in effect and cheaper to purchase. The greater safety of sebastine depends on two circumstances—first, that the explosive oil is more completely absorbed and bound by a specially prepared kind of charcoal and other ingredients;

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* This subject has previously received much consideration from Professor Åkerman, whose valuable paper on "The Generation of Heat during the Bessemer Process," will be found in the *Journal of the Iron and Steel Institute* for 1872, vol. ii., 110.

and next, in ordinary cases it requires no percussion cap to explode. As to use in mining, it is reported that the new sebastine is exploded simply by the fuse, providing the bore-hole is properly secured by a stronger wadding, as in an ordinary charge of blasting powder. According to official statements there has not been one single instance of accident happening when using the new sebastine. The Swedish Government having ordered trials of sebastine against dynamite, it is said to have been proved that sebastine was superior in effect and about equal in force to English gun-cotton when used in torpedoes. The Consul at Gothenburg adds:—"As an explosive of great power, and offering superior security, particularly for mining and similar purposes, I would recommend the new sebastine, or more properly, its improved form, virite, to the notice of her Majesty's Government."

A New Direct Process.—A new modification of the Osmund or Catalan process has been under experiment for some time in Sweden with the view of giving iron free from phosphorus, by direct process. Professor Särnstron describes in *Jern Kontoret's Annaler* the results obtained by this process in a charcoal furnace at Wyhammer.

The furnace in question consisted of a reduction shaft connected with hearths by small culverts. These hearths can be closed, having vertical dampers with holes at their lower parts in order that the gases generated by the fuel may pass through the shaft and thus act the part of gas in an ordinary blast furnace. The dampers are balanced, and are therefore easily raised and lowered, the culverts being also furnished with single bricks, by removing which the necessary repairs to the furnace can be done, but which at other times close the furnace. Should it be desired to cut off the shaft from the remainder of the furnace, this can be done by a horizontal damper, which can be drawn closely over the hole. The operation of the furnace is as follows:—Charcoal and ore are charged in the shaft in proper proportions, either by a special apparatus or in the common way. The ore will then, as it settles in the shaft, be subjected to the same process of conversion as in the ordinary reduction-zone of a blast furnace. In order to transfer the spongy iron to another hearth, a hook is passed through the upper working holes in the dampers of the culvert through which the operation of raking down is effected in order to keep the hearth always well filled with charcoal and iron until the smelting is nearly effected; but when it is desired to remove the mass of iron, the raking down is stopped, and the bloom is allowed to go down in the hearth. It may then be easily broken up when one of the dampers is opened. During this operation one fire-place should be kept charged, as the gas pressure in the furnace should always be higher than the pressure of air from without, in order to prevent all suction of air through the open hearth. As soon as the bloom is removed and the hearth cleaned out, it is again closed and refilled with charcoal and iron, by raking down from the shaft as before, and the blast is then turned on. In the same way the process may be alternated with the other hearths. The furnace at Nyhammar was 16 feet high, with a cubic diameter of 16 feet above and 18 below, and was made of firebrick. It contained 302·4 cubic feet of charcoal. The fittings were made of bar iron, and were very similar to those used in the Lancashire hearths. The dimensions were as follows:—Distance between upper rim of tuyeres, 2 feet; but, in order to facilitate the extraction of the bloom, they were made to slope an inch outward, being thus 2 inches less at the bottom. From the back, which was perpendicular, to the front wall, the distance was 2 feet, with 3 inches slope outward. The depth of the hearth was 1 foot, and the tuyeres reached an inch into it, with a dip of about 22°, their width at the nozzle being $\frac{7}{8}$ by $\frac{7}{8}$ inch, with the upper sides semicircular. The shaft was capable of holding from 22 to 23 charges of two barrels of charcoal each, being about 290 cubic feet for each operation, and one operation was generally effected in twenty-four hours. In most of the experiments two barrels—12·6 cubic feet—of charcoal to 3 cwt. of ore were used, but towards the end of the operation the quantity of ore was reduced to 2 cwt., *i.e.*, to 1 cwt. per barrel of charcoal (6·3 cubic feet), and this proportion was found advantageous, both as regards the ore and the quantity of fuel consumed, in proportion as the ores contained more or less phosphorus.

The experiments referred to were commenced in November, and continued till about the middle of December, and then resumed, with a few interruptions, from January until March last. The results arrived at during this period were, of course, variable, as the object kept in view was to find the best relation between the hearths, their diameter, the number of the tuyeres, their size, dip, pressure of the blast, &c. The results here given are thus only such as tend to show what might be effected with such a furnace. The following are the particulars of the working during the last few weeks. The ores used were uncalcined, from the Väss mine in Gränges Berget, a famous deposit in Sweden. They contained about 60 per cent. of iron, and 0·91 of phosphorus, and were charged with 1 cwt. of ore per barrel of charcoal, or 1 cwt. of ore to 6·3 cubic feet of charcoal. The results of five shifts are appended:—

	Consumption of Charcoal.	Consumption of Ores.	Yield of Iron.
	Barrels.	Cwts.	Cwts.
One day-shift .	23	20	11·40
Do. do. .	24½	22	11·60
Do. do. .	7	6	4·00
One night-shift	25	22	10·65
One day do.	21	18	10·80
	100½*	88	48·45

* = 633 cubic feet.

As 12½ of these 100½ barrels were consumed in the fireplace, the actual quantity of fuel used in making the iron was only 88 barrels, or 554·4 cubic feet for the smelting of some 88 cwt. of ores, the relative consumption being therefore 2·07 barrels, equalling 13·04 cubic feet of charcoal, and 1·80 cwt. ore per cwt. of iron returned. The actual returns of iron were thus 55·05 per cent. of the materials charged.

Experiments were made at Löderfors with the same method. The shaft was in this case 16 ft. high, and capable of containing ten charges of two barrels, viz., 12·6 cubic ft., each being about half the quantity, therefore, of the one erected at Nyhammar. The make here was 16 cwt. of pig iron per shift, with a consumption of 25·2 cubic feet of charcoal per cwt. of pig, and about ½ cwt. of ore per barrel of charcoal = 6·3 cubic feet.

It is claimed, therefore, that the process, with certain modifications, might be successfully applied to the working of charcoal iron with ores moderately rich in phosphorus, which is largely expelled during the operation. A complete translation of the paper of Professor Särnstrom has appeared in *Iron* (London), and in the *Iron Age* (New York).

OTHER COUNTRIES.

Africa.—Iron Mining.—Mr. Pinto, in describing the method of mining iron ore as practised in Africa, states that during the coldest months—that is to say, June and July—the miners leave their homes and take up their abode in extensive encampments near the iron mines, which are abundant in the country. In order to extract the ore, they dig circular holes or shafts from 10 to 13 ft. in diameter, but not more than 6 or 7 ft. deep; this arising, most probably, from the want of suitable means to raise the ore to greater elevations. Mr. Pinto examined several of these shafts, and found them all of a similar character. As soon as enough ore for the work of the year has been extracted, the operation of separating the iron is commenced. This is done in holes of no great depth, the ore being mixed with charcoal, and the temperature being raised by means of primitive bellows, consisting of two wooden cylinders about 1 ft. in diameter, hollowed out to a depth of 4 in., and covered with two tanned goat-skins, to which are fixed two handles, 20 in. long and ½ in. thick. By a rapid movement of these handles, a current of air is produced which plays upon the charcoal through two hollow wooden tubes attached to the cylinder, and furnished with clay muzzles. By incessant labour, kept up night and day, the whole of the metal becomes transformed by ordinary processes into spades, axes, war hatchets, arrow-heads, nails, knives, and bullets for firearms, and even firearms themselves, the iron being tempered with grease and salt. Mr. Pinto reports that he has seen a good many of these guns carry as well as the best pieces made of cast steel.

Cape of Good Hope.—Boring Operations with Boart.—According to a correspondent of the *Times*, it seems that in the course of some boring operations, which have recently been carried on by the Government of the Cape of Good Hope in search of coal, it occurred to the geologist in charge to make trial of native boart in lieu of the Brazilian carbonado, which had, until then, been employed. The experiment proved a complete success. The last six crowns used were of three inches diameter, set with boart. It was found that these bored through 1100 feet of sandstone and shale, part of it exceedingly hard, being indurated by contact with intrusive rock. The average boring per crown was therefore 183 feet, and the last crown is nearly as good as new. Of the above six crowns, one bored through 322 feet 7 inches, and was still usable, while another bored through 350 feet. In precisely the same class of country, eight crowns supplied from London, and set with carbonado, bored only 30 feet each. The boring effected with the latter cost at the rate of 27s. 6d. per foot; while the work done with boart, in the same class of rock, cost less than 2s. per foot bored. The advantage in the use of boart is increased by the fact that, owing to the greater depth bored by a single crown, there is less delay caused by the resetting of the stones. Great care is, however, necessary in the selection of boart for the purpose, as a very large percentage of the ordinary boart of commerce is unsuitable.

China.—Coal Mining.—It is stated in a recent report that extensive mining operations are now being carried on in China. At Keelung there is a Government colliery from which no less than 54,000 tons of coal have been raised during the last year, as compared with 41,000 tons in the year 1880. During the year 1881, 60,000 tons of coal were disposed of—that is to say, the colliery has succeeded in selling 6000 tons over the total output for the year. We understand that the colliery at Keelung was sunk, developed, and managed by North of England sinkers, underground and surface overmen, working under the control of Mr. David Tyzack, a North of England mining engineer. When that gentleman left the Island of Formosa, some three months ago, the colliery was raising above 2000 tons of good steam coal per week, employing Chinese labour alone. It is possible that the output for the current year may reach 100,000 tons, if the Mandarins who direct the amount to be raised for Government use so wish it. Four engines are at work at Keelung Imperial Colliery, viz., two winding machines, one underground hauling engine, and the Guibal fan engine, all in the hands of Chinese natives, who, up to within five years ago, had never seen such things in their lives.

Honduras.—Dr. W. G. K. Fritzgaertner, geologist and mineralogist to the Government of the Republic of Honduras, in a recent report states that whole mountains of fine magnetic iron exist both near the coast and in the interior. The natives use clean and fine ore directly in their forges. The iron produced is of a very superior quality, and greatly resembles steel in all its characteristics. Coal is very abundant on the Atlantic coast, near the river Uloa, the quality being a semi-bituminous kind. As the quantity seems to be quite considerable, this mineral will, in the near future, become a valuable article of commerce along the Caribbean coast.

Mining property is not taxed, and there is no duty on the exportation of ores or bullion; while the Government is so anxious to encourage the industry that it will render all assistance in its power for the transportation of machinery, and will free it of importation duties.

India.—The Government and the Iron Industry.—It is officially intimated that the Government of India have for some time past had under their consideration the importance of developing the iron industry in India. In Assam, Kuch Behar, Burmah, and the Kumaon ranges the prospects are promising, to a greater or less extent. In Lower Bengal, and Ranigunj district, Sonthali, and Chutia Nagpur; in the Central Provinces, Sumbalpur, and Chanda; in Central India, in the ranges near Gwalior, and in the Punjaub, numerous localities are found to be specially endowed with all the requisites for successful production. In recalling these facts, and inviting the consideration of capitalists, the Viceregal Government state that in quality the ores are mostly found to be extremely pure, and, where the proportion of impurities is large, recently invented processes have removed all obstacles to their successful elimination. It appears, therefore, that India possesses the means of supplying all her wants in respect of cast iron, wrought iron, and steel, and it is claimed that the supply could be produced remuneratively on a strictly commercial basis. Nothing appears to be necessary in order to attract private enterprise to so eligible an opening except the collection and diffusion of sufficient information, and the grant of such facilities as the State may legitimately and reasonably afford to a young and growing industry. The Indian Government point out, however, that private enterprise in this matter must evidently be on a large scale, and not confined to one locality alone. The distances in India are so great, and the railway system now so extended, that the cost of conveying material to the spot where it is needed is an important factor in every calculation. It has been proved that unless works were established in four different localities, the cost of sending old rails and tyres to be worked up afresh would exceed that of obtaining new ones from England. Towards the development of the industry in the Ranigunj district the attention of the Government has in the first instance been directed, in consequence of the fact that a private company was established a few years ago, but after a short time it fell into difficulties. After carefully investigating the causes of failure, the Government of India came to the conclusion that the only way in which the works could be at any early date placed in the hands of experienced persons, having an adequate command of capital, was by an intermediate purchase on the part of the State. The Bengal Ironworks have, therefore, been purchased for the sum of 430,761 rupees, and the Viceroy now announces that his Council will be ready to transfer them for that sum, together with any further indispensable outlay, to any parties who may establish satisfactorily that they are in possession of sufficient skill and resources, and who are prepared to carry on the manufacture of iron and steel upon a scale commensurate with the probable needs of that portion of British India which is within a reasonable distance of the works. The Governor-General in Council will be further prepared to enter into an engagement for ten years at fixed prices to be agreed upon.

Italy.—Mineral Production of the Island of Elba.—The raising of iron ores is the only industry of this island. Four mines out of six are in operation, employing 1200 hands. The average earnings are about two francs a day. The mineral is first washed, and then stored for export. In 1880 the output was 287,680 tons, against 218,260 in 1879, which shows an increase of about 31 per cent. The price averaged 14·75 francs per ton.

The Italian Government has, it is said, limited the output from the 1st January 1881 to 250,000 tons per annum. The mines are worked by the "Banque Générale des Mines de l'Elbe," who have their offices at Livourne.

The export in 1879 was 282,802 tons; in 1880, 350,084 tons. The export was distributed among different countries as follows:—

Year.	France.	England.	Italy.	Total.
1880 . . .	42,868	281,542	25,674	350,084
1879 . . .	21,905	249,996	10,901	282,802

Natal.—The Character and Extent of the Coalfields.—A report of the first geological survey which has been made in the colony of Natal has recently appeared. It is contributed by Mr. Frederick North, and has special reference to the coal deposits which are found in the colony, but it likewise shows that valuable iron ore also exists in very considerable quantities. At present, however, the chief interest centres on the practicability of working the coalfields, and thereby developing the mineral resources of Natal. Accompanying Mr. North's report is a tabulated statement of results obtained from a series of trials of colonial coal upon the Natal Government railways, which are encouraging in relation to the utilisation of this coal in the future. Coal exists in Victoria County, which is situated on the coast between Durban and the Tugela river, and it is also found in two or three other localities up the country. The principal fields, however, are situated in the northernmost district of the colony, lying, generally speaking, between Newcastle and Ladysmith. Of course, the primary difficulty in the way of profitably and advantageously working these fields is that of transit; but a railway is now in course of construction from Pietermaritzburg to Ladysmith, which, it is hoped, will afford the required facilities for the transmission of the coal to the coast. Mr. North wrote to Chief John Dunn with reference to the coal found in Zululand, and he was furnished with samples which the chief himself considered to be of inferior quality. This opinion was shared by Mr. North, who described the coal as being "like bad peat." No coal that he obtained from Zululand was, he says, at all equal to the coals of Dundee or Newcastle. Indeed, it may be assumed that the chief supply of good coals will be obtained from that district of the colony in which those towns are situated. In reporting to the Colonial Secretary of Natal the result of his survey, Mr. North says that his object throughout his labours was to ascertain as accurately and as conclusively as possible the probable area of the workable coals, their thickness, commercial value, and quality for various kinds of work, whether for steam or gas, for smithy or household consumption; but the great questions to which he continually applied himself were, "Will this coal, the produce of the colony, be of any service for locomotive purposes, and if so, what is the quantity to be relied upon; and, further, what will be the pecuniary annual advantage derived by the colony, providing the colonial fuel can be used instead of imported coal?" These questions he was able to answer satisfactorily; for he declares that "both analysis and experiment have now proved that the coal may be used with economy in the locomotive. Some of the most free-burning will make gas; most of it, if properly mixed, will make good house-coal, and some of it is specially adapted for general steam purposes." Mr. North's investigations led him to conclude that the area of the coalfield available for working is 1350 square miles; that this area, assuming an average thickness of 4 feet, and allowing the ample deduction of 50 per cent. for faults, worthless coal, and barren ground, contains 2,073,000,000 tons; and that a large proportion of these coal deposits are either in crown lands or upon farms, the land of which has been disposed of, but the right to work coal reserved to the Government. At the same time he declares that for railway communication the economical distribution of the produce of this isolated coalfield is absolutely needful if it is to have any chance of development.

Spain.—Manganiferous Ores in the Murcia District (*Stahl und Eisen*, Nov. 1882).—The French Consul in Carthagena has published a report on the manganiferous iron ores of the Murcia district. The occurrence is a very extensive one, and the mining operations are inexpensive, as the pits are not deep. During the years 1879, 1880, and 1881 something between 500,000 and 600,000 tons were raised and exported to France, England, and the United States. The ore averages 15 to 18 per cent. Mn and 30 to 36 per cent. iron. The price varies greatly according to the richness. It is calculated on the basis of ·60 to 1·00 francs per unit of manganese and ·12 to ·16 francs per unit of iron, so that the best ore is worth 22·8 francs, the poorest only 13·82 francs at the shipping port. Ordinary hematites are not mined to any considerable extent in the Carthagena district. The output amounts to from 100,000 to 150,000 tons, which mostly remains in the country.

Spain.—The Iron Industry of Bilbao.—The *Revista Minera* (Madrid, October 24) announces that between January 1st and September 30th of the present year, the foreign exports from the port of Bilbao have amounted to 2,875,500 tons of iron and other ores, and 31,906 tons of sundry merchandise. The manufacture of iron and steel in the Bilboa district is being rapidly extended, and a number of new works are projected. A company with a capital of twenty-five millions pesetas (£1,000,000) has been formed in Madrid for the establishment of large works on the same lines as those of Creusot, Cockerill, and Krupp, and similar to that already carried on by Messrs. Ibarra.

Spain. — Geological Map. — The Commission appointed by the Government to prepare a geological map of Spain has now completed the drawing of the work. It is on the scale of 1 to 400,000, and its size will be 13 ft. 1½ in. by 9 ft. 10 in. This scale has been adopted because it is that of the local maps which have already been published. A full description of the various mining districts will also be issued by the Commission.

THE END.

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THE

IRON AND STEEL INSTITUTE.

ESTABLISHED 1869.

LIST OF MEMBERS,

RULES, &c.

◆

London:
VICTORIA MANSIONS, VICTORIA STREET.
1883.

THE

IRON AND STEEL INSTITUTE.

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BAGNALL, CHARLES, Whitby.
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EVANS, WILLIAM, Bradford.
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DAVID DALE, DARLINGTON.

General Secretary.

J. S. JEANS, VICTORIA MANSIONS, VICTORIA STREET, LONDON, S.W.

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APPENDIX.

Form A—CANDIDATE'S RECOMMENDATION FOR ELECTION.
Form B—NOTICE OF ELECTION OF MEMBER.
Form C—OBLIGATIONS UNDERTAKEN BY ELECTED CANDIDATES.
Form D—APPLICATION FOR ARREARS OF SUBSCRIPTION.

THE IRON AND STEEL INSTITUTE.

RULES.

1. The Society shall be designated "THE IRON AND STEEL INSTITUTE."

2. The objects of the Institute shall be—

To afford a means of communication between members of the Iron and Steel Trades upon matters bearing upon their respective manufactures, excluding all questions connected with wages and trade regulations.

To arrange periodical meetings for the purpose of discussing practical and scientific subjects bearing upon the manufacture and working of iron and steel.

SECTION I.—**Constitution.**

3. The Institute shall consist of members who shall be more than twenty-one years of age, and shall have one or other of the following qualifications:—

(*a*) Persons practically engaged in works where iron or steel is produced or worked.

(*b*) Persons of scientific attainments in metallurgy, or specially connected with the application of iron and steel.

It shall be within the province of the Council to elect Honorary Members, the number not to exceed twenty.

SECTION II.—**Election of Members.**

4. A recommendation for admission according to Form A in the Appendix shall be forwarded to the General Secretary, and by him be laid before the Council. The recommendation shall be in writing, and be signed by not fewer than three members.

5. Such applications for admission as are approved by a majority of the Council shall be inserted on a voting list. This voting list shall specify the name, occupation, address, and proposers of the candidates, and shall be forwarded to the members at least fourteen days previous to the next general meeting, when the lists that have been returned to

the General Secretary shall be opened, only in presence of the members, by Scrutineers, to be appointed by the meeting for that purpose. The elections shall take place at the general meetings only.

[*Note.—Gentlemen whose proposal forms are passed by the Council after the voting lists have been issued, shall be allowed to attend the subsequent general meeting; and if afterwards duly elected members, it is understood that their subscription becomes payable in respect of the year in which said meeting is held.*]

6. The election shall take place by ballot, three-fifths of the votes recorded being necessary for election.

7. When the proposed candidate is elected, the General Secretary shall give him notice thereof, according to Form B, but his name shall not be added to the list of members of the Institute until he shall have paid his first annual subscription, and signed the Form C in the Appendix.

8. In the case of non-election, no mention thereof shall be made in the minutes, nor any notice given to the unsuccessful candidate.

SECTION III.—**Officers and Mode of Election.**

9. The officers of the Institute for the management of its affairs shall consist of one President, nine Vice-Presidents, fifteen Members of Council, a Secretary or Secretaries, and one Treasurer. All members who have filled the office of President of the Institute shall be *ex-officio* permanent members of the Council, under the title of Past Presidents.

10. The President shall be elected for two years, and shall not be eligible for re-election until after an interval; three Vice-Presidents and five Members of the Council, in rotation, shall retire annually, but shall be eligible for re-election, unless disqualified by non-attendance during the previous year. In addition, those Vice-Presidents and Members of Council shall retire who have not attended any meeting of the Council or Institute during the previous year, unless such non-attendance has been caused by special circumstances, which shall have been duly notified to the Council.

11. Candidates shall be put in nomination at the ordinary general meeting preceding the annual meeting, when the Council shall present a list specifying which of the number are eligible for re-election. Any member shall be then entitled to add names to the list of candidates. Members may also nominate candidates for office up to one month previous to the annual meeting, the names to be sent to the General Secretary. The voting list of the proposed names shall be forwarded to the members, and must be returned to the General Secretary previous to the election.

12. Each member may erase any name or names from the lists, but the number of names on the list, after such erasure, must not exceed the number to be elected to the respective offices as before enumerated. The lists which do not accord with these directions shall be rejected by the

Scrutineers. The votes for any member who may not be elected as President or Vice-President shall count for him as Vice-President or other member of the Council. The voting to be conducted in the manner specified in Section II.

13. The Council shall have power to fill up any vacancies that may occur during their year of office.

SECTION IV.—**Duties of Officers.**

14. The President shall be Chairman at all meetings at which he shall be present, and in his absence one of the Vice-Presidents. In the absence of a Vice-President, the members shall elect a Chairman for that meeting.

15. The Treasurer shall hold in trust the uninvested funds of the Institute, which shall be deposited in the name of the Society at a bank approved by the Council; he shall receive all moneys, and shall pay all accounts that are properly certified as correct by the Council; and shall present, from time to time, a statement of the Society's accounts.

16. The General Secretary shall attend all meetings, shall take minutes of the proceedings, shall be responsible for the safe custody of all papers, books, and other property of the Institute, and, under the direction of the Council, shall conduct the general business of the Institute.

SECTION V.—**Meetings.**

17. There shall be at least two general meetings in each year, one of which shall be held in London in the Spring, and the other in August or September, in such locality as the Council may direct. The meeting in the Spring shall be the annual meeting for the election of officers.

18. Twenty members shall be entitled to call, through the General Secretary, a special meeting, the objects thereof to be stated in the requisition. The business of such meeting shall be confined to the special subjects named in the notice convening the same.

19. All members shall have notice of, and shall be entitled to attend, each meeting of the Institute, and to receive copies of the Institute's publications gratuitously.

20. No alteration of the Rules or Bye-laws shall be made except at the annual meeting, and a notice of any proposed alterations shall be given at the general meeting to be held in August or September.

SECTION VI.—**Subscriptions.**

21. The subscription of each member shall be two guineas per annum; and members elected after January 1st, 1870, shall pay an entrance fee of two guineas each.

22. The subscriptions shall be payable in advance on January 1st in each year. Any member whose subscriptions shall be twelve months in

arrear shall forfeit all the privileges of the Institute; and the Council, after having given due notice, in the form D in the Appendix, shall be empowered to remove such name from the lists of the Institute.

SECTION VII.—**Communications of Members.**

23. All communications shall be submitted to the Council, and, after their approval, shall be read at the general meetings.

24. All communications made to the Institute shall be the property of the Society, and shall be published only in the Transactions of the Institute, or by the authority of the Council.

SECTION VIII.—**Property of the Institute.**

25. All the property of the Institute, other than funds in the hands of the Treasurer, shall be held by three Trustees, in trust for the Society. The Trustees shall be appointed by the members in general meeting assembled; and in case any vacancy in the Trustees occurs, the same shall be filled by election at the next general meeting—the Chairman, in all cases, having a second or casting vote.

26. All books, drawings, communications, models, and the like, shall be accessible to all members according to the Bye-laws. The Council shall have power to deposit the same in such place or places as may be considered most convenient for the members.

27. Every person desirous of bequeathing to the Institute any personal property, is requested to make use of the following form in his will:—"I give and bequeath to the Trustees of the Iron and Steel Institute in London [here mention the property or sum of money intended to be bequeathed] for the use of the Institute."

SECTION IX.—**Consulting Officers.**

28. The members in general meeting assembled shall have power to appoint such consulting officers as may be thought desirable from time to time, and may vote them suitable remuneration.

SECTION X.—**Prizes.**

29. The Society may offer annually a certain sum to be appropriated in Prizes or Medals, for Essays on subjects prescribed by the Council, for inventions of a specified character, or for improvements in special departments of the iron or steel manufactures. A list of the subjects for which prizes will be given shall be presented in each Annual Report.

SECTION XI.—**Dissolution.**

30. The Institute shall not be broken up unless upon the vote of two-thirds of the members present at any general meeting, convened for the

purpose of considering the dissolution; and after confirmation by a similar vote, at a subsequent meeting, to be held not less than three, or more than six months after the first; and notice of this last meeting shall be duly advertised as the Council or a general meeting may advise.

APPENDIX.

FORM A.

Mr. A. B. (address in full), being of the required age, and desirous of becoming a member of the Iron and Steel Institute, we, the undersigned, from our personal knowledge, do hereby recommend him for election.

His qualifications are ____

____

Witness our hands this ________ day of ________ 18

________________________ }
________________________ } *Names of Three Members.*
________________________ }

FORM B.

Sir,—I beg to inform you that on the ____________ you were elected a member of the Iron and Steel Institute, but, in conformity with the Rules, your election cannot be confirmed until the accompanying form be returned with your signature, and until your entrance fee and first annual subscription (amount £________) be paid to me. If the first subscription is not received within two months of this date, your election will become void.

I am, Sir, your obedient Servant,

________________________ *General Secretary.*

______ day of ________ 18

FORM C.

I, the undersigned, being elected a member of the Iron and Steel Institute, do hereby agree that I will be governed by the regulations of the said Institute, as they are now formed, or as they may be hereafter altered, that I will advance the interests of the Institute as far as may be in my power, provided that, whenever I shall signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand this__________day of__________ 18

FORM D.

Sir,—I am directed to inform you that your subscription to the Iron and Steel Institute, amounting to________ is in arrear, and that if the same be not paid to me on or before the ________day of__________ 18____, your name will be removed from the lists of the Institute.

I am, Sir, your obedient Servant,

__________________ *General Secretary.*

LIST OF MEMBERS.

CORRECTED UP TO DECEMBER 31st, 1882.

HONORARY MEMBERS.

His Majesty THE KING OF THE BELGIANS, care of Belgian Ambassador, 36 Grosvenor Gardens, London, W.

Professor PETER RITTER VON TUNNER, Leoben, Austria.

Professor R. ÅKERMAN, School of Mines, Stockholm, Sweden.

Professor GRÜNER, 90 Rue d'Assas, Paris, France.

Herr F. KRUPP, Essen, Rhenish Prussia.

Mr. PETER COOPER, 17 Burling Slip, New York.

Dr. PERCY, 1 Gloucester Crescent, Hyde Park, London, W.

ORDINARY MEMBERS.

*Those Marked * are Original Members.*

Elected Member	
1878	Abel, Fredk. Augustus, C.B., F.R.S., *Royal Arsenal, Woolwich, S.E.*
1870	Adams, George, *Priestfields, near Wolverhampton.*
1875	Adams, George F., *Cardiff.*
1872	Adams, Jno., *Hollinswood, near Wellington, Salop.*
1869	*Adams, William, *Cardiff.*
1869	*Adamson, Daniel, *Dukinfield, Manchester.*
1872	*Addie, James, *Langloan Iron Works, Coatbridge, N.B.*
1869	*Addie, John, *Langloan Iron Works, Coatbridge, N.B.*
1880	Addyman, Thos., *West Gorton, Manchester.*
1869	*Ainslie, W. G., 3 *East India Avenue, Leadenhall Street, London, E.C.*
1872	Ainsworth, George, *Consett Iron Works, Consett, County Durham.*

Elected Member	
1869	*Aitken, Henry, *Almond Iron Works, Falkirk, N.B.*
1879	Aiton, John, *Milnwood Iron Works, Holytown, N.B.*
1881	Akrill, Charles, *Golds' Green Foundry, West Bromwich.*
1875	Albright, A., *Mariemont, Birmingham.*
1872	Alexander, Edward, *Villa Ada, Intra, Lago Maggiore, Italy, and* 5 *Old Square, Lincoln's Inn, W.C.*
1880	Alger, Charles, *Hudson, New York, U.S.A.*
1875	Allen, Alfred H., 1 *Surrey Street, Sheffield.*
1881	Allen, George, 101 *Leadenhall Street, London, E.C.*
1872	Allen, William Daniel, *Bessemer Steel Works, Sheffield.*
1880	Allen, W. E., *Well Meadow Steel Works, Sheffield.*
1869	*Alleyne, Sir John G. N., Bart., *Chevin, Belper.*
1875	Alleyne, Reynold Henry Newton, *Coxbench Hall, Derby.*
1879	Allison, Hy. Thos., *Palmer's Shipbuilding and Iron Company, Jarrow-on-Tyne.*
1875	Allott, Alfred, 6A *Austin Friars, London, E.C.*
1874	Allport, Charles J., 161 *Queen Victoria Street, E.C.*
1871	Allport, Howard Aston, *The Park, Nottingham.*
1880	Anderson, C., *Osborne Terrace, Leeds.*
1874	Anderson, Samuel, *Westbury Iron Works, Wiltshire.*
1875	Anderson, William, *Lesney House, Erith, Kent.*
1880	André, Emil., *Eschweiter Ané, Germany.*
1880	Andrew, J. A., *Toledo Steel Works, Sheffield.*
1881	Andrew, J. H., *Oak Lawn, Sheffield.*
1873	Angus, Robert, *Lugar Iron Works, Cumnock, Ayrshire.*

Elected Member	
1880	Annable, W., *Govan Steel Works, Glasgow.*
1875	Anstice, R. E., *Madeley Wood, Iron Bridge, Salop.*
1875	Anstice, J. A., *Madeley Wood, Iron Bridge, Salop.* } retired 1879.
1879	Appleby, C. J., 89 *Cannon Street, E.C.*
1875	Arkinstall, Charles, *Highfield, West Bromwich.*
1873	Armstrong, Joseph, *Brinsworth Iron Works, Rotherham.*
1869	*Armstrong, Sir William G., C.B., *Elswick Iron Works, Newcastle-on-Tyne.*
1881	Ascherson, E., 34 *Old Broad Street, London, E.C.*
1875	Ashbury, Thomas, 215 *Plymouth Grove, Manchester.*
1880	Atkinson, A. J., *Blaenavon, Pontypool, Monmouthshire.*
1879	Atkinson, M. H., 21 *Windsor Terrace, Newcastle-on-Tyne.*
1882	Austin, S. Kennith, *Benthir Axle Box Co., Birmingham.*
1881	Baare, Fritz, *Bochum, Westphalia.*
1874	Backhouse, Charles James, *St. John's, Wolsingham, Darlington.*
1873	Bagley, Charles Jno., *Tees Bridge Iron Works, Stockton-on-Tees.*
1869	*Bagnall, Charles, *Grosmont Iron Works,* viâ *York.*
1872	Bagnall, Thomas, Jun., *Milton Ernest Hall, Bedford.*
1877	Bagshawe, Washington, *Newburn Steel Works, Newcastle-on-Tyne.*
1873	Bain, Sir James, 3 *Park Terrace, Glasgow.*
1874	Bain, J. R., *Harrington Iron Works, Harrington, Cumberland.*
1880	Baird, Geo., 13 *Berkeley Square, W.*
1873	Baird, William, *Albert Place, Airdrie, N.B.*
1875	Bakewell, Jas. G., *Longton Hall Colliery, Longton, Staffordshire.*

Elected Member	
1882	Baldry, Jas. D., 2 *Queen Square Place, S.W.*
1869	*Baldwin, Alfred, *Wilden, near Stourport.*
1877	Bamlett, A. C., *Thirsk, Yorkshire.*
1880	Banister, F. Dale, 117 *Denmark Hill, London, S.E.*
1869	*Banks, George H., *Rhiwderin Tin Plate Co., Newport, Monmouthshire.*
1869	*Bantock, Thomas, *Merridale House, Wolverhampton.*
1879	Barba, Joseph, *Creusot, France.*
1876	Barber, Jno., 14 *Park Row, Leeds.*
1879	Barber, James Hy., *Sheffield Iron and Steel Works, Attercliffe, Sheffield.*
1880	Barbour, Thos., *Derwent Hematite Iron Works, Workington.*
1876	Bargate, George, *Dalton-in-Furness.*
1869	*Barker, George J., *Chillington Iron Works, Wolverhampton.*
1869	*Barker, Thomas, *Queen Steel Works, Sheffield.*
1879	Barnaby, Nathaniel, C.B., *Admiralty, S.W.*
1874	Barnard, Clement, 4 *Billiter Square, London, E.C.*
1873	Barningham, Thomas, *Darlington.*
1874	Barratt, William, *Holly How, Coniston, Windermere.*
1869	*Barrett, Wm., *Norton, Stockton-on-Tees.*
1882	Barrett, Wm. Henry, *care of Senõr Don José M. Martinez de las Rivas, Bilbao, Spain.*
1881	Barrow, Edwd., 188 *Rue Royale, Brussels.*
1880	Barrow, James, *Maesteg, Glamorganshire.*
1869	*Barrows, William, *Bloomfield Iron Works, Tipton.*
1869	*Bartholomew, Charles, C.E., *Castle Hill House, Ealing, W.*
1869	*Barton, Edward, *Carnforth Hematite Iron Works, Carnforth.*

Elected Member	
1881	Bayard, Paul, *Pompey, France.*
1873	Bayley, Jno. Clowes, 1 *Queen Victoria Street, E.C.*
1881	Bayliss, Moses, *St. Cuthbert's, West Heath Road, Hampstead, N.W.*
1881	Bear, F. Drew, 113 *Queen Victoria Street, London, E.C.*
1880	Beard, A., *Landore Siemens Steel Works, Swansea.*
1882	Beardmore, Isaac, *Parkhead Iron and Steel Works, Glasgow.*
1878	Beardmore, William, *Parkhead Rolling Mills, Glasgow.*
1872	Beaumont, Col. F. E. B., *Westminster Palace Hotel, S.W.*
1881	Beckett, J. S., *Brooklyn Works, Sheffield.*
1882	Beckwith, Jno. H., *Knott Mill Iron Works, Manchester.*
1869	*Bedson, George, *Bradford House, Manchester.*
1874	Bedson, Joseph P., *Bradford Iron Works, Manchester.*
1876	Bell, Charles Lowthian, *Middlesbrough.*
1874	Bell, Edward M., *Tin Plate Works, Coatbridge, N.B.*
1869	*Bell, I. Lowthian, F.R.S., *Rounton Grange, Northallerton.*
1869	*Bell, John, *Saltburn-by-the-Sea, Yorkshire.*
1875	Bell, J. H., *Walker Rolling Mills, Walker-on-Tyne.*
1869	*Bell, John T., *Monkwearmouth Iron Works, Sunderland.*
1869	*Bell, Thomas, *Bilbao, Spain.*
1869	*Bell, T. Hugh, *Clarence Iron Works, Middlesbrough.*
1872	Bell, Thomas, Jun., *Clarence Iron Works, Middlesbrough.*
1878	Bender, Dr. August, *Essen, Rhenish Prussia.*
1869	*Bennett, Peter D., *Horseley Works, Tipton.*
1880	Bennett, W., 109 *Shaw Street, Liverpool.*

Elected Member	
1881	Benson, R. Seymour, *Benfieldside Edge, Blackhill, County Durham.*
1873	Bergen, A. Von., *Middleton Iron Works, Darlington.*
1869	*Bessemer, Sir Henry, F.R.S. *Denmark Hill, London, S.E.*
1871	Bewick, T. J., *Haydon Bridge, Northumberland.*
1875	Birch, George, 3 *Brentwood, Pendleton, Manchester.*
1870	Birch, John, *Railway Steel and Plant Company, Manchester.*
1882	Birkbeck, George, 17 *Hartington Street, Barrow-in-Furness.*
1873	Bishop, Frederick, *Welwyn Lodge, Swansea.*
1878	Bissell, James B., *Birchills Iron Works, Walsall.*
1874	Black, John, *Commonhead, Airdrie, N.B.*
1875	Blair, Thomas, *Atlas Works, Sheffield.*
1869	*Blair, Thomas S., *Pittsburg, Pennsylvania, U.S.A.*
1878	Blake, Thomas, *Stockton-on-Tees.*
1879	Blakemore, Wm., *Tondu Iron Works, Bridgend, Glamorganshire.*
1881	Bleckly, C. A., 61 *King William Street, London, E.C.*
1878	Bleckly, Herbert Sanderson, *Altrincham, Cheshire.*
1869	*Bleckly, John James, *Warrington.*
1869	*Bleckly, W. H., *Thelwall Lea, near Warrington.*
1880	Blumer, Jno. G., *Darlington.*
1882	Böcking, Edw., *Mulheim-on-Rhine, Germany.*
1869	*Bodmer, J. J., *Dashwood House, New Broad Street, London, E.C.*
1881	Bolano, H. G., 49 *and* 50 *Parliament Street, S.W.*
1869	*Bolckow, C. F. H., *Marton Hall, Middlesbrough.*
1880	Bollinger, Henry, *Milan, Italy.*

Elected Member	
1874	Bolton, Thomas, 75 *Newhall Street, Birmingham.*
1876	Boulton, William, *Yarlside Mines, near Dalton-in-Furness.*
1872	Bourne, John.
1881	Bower, George, *St. Neots, Huntingdonshire.*
1882	Bowman, Harold, *Knott Mill Iron Works, Manchester.*
1873	Bowser, Howard, *Charles Street, Glasgow.*
1882	Boyd, A. C., *The Lakes, Dukinfield.*
1874	Braby, Frederick, *Cathcart House, South Kensington.*
1874	Bradshaw, J. B., *Rotherwood Iron and Steel Co., Rotherham.*
1876	Braggiotti, F. M., *Queen Street, Newcastle-on-Tyne.*
1882	Bramfels, H. S. H. Prince Albert S., *Schloss Bramfels, Wetylar, Prussia.*
1882	Bramwell, Sir F. J., 37 *Gt. George Street, Westminster, S. W.*
1873	Brand, James, 123 *High Street, Glasgow.*
1879	Brauns, Hermann, *Union Works, Dortmund, Germany.*
1869	*Briggs, Joseph, *Iron Foundry, Barrow-in-Furness.*
1880	Brock, A., 110 *Cannon Street, London, E.C.*
1881	Brock, C. J., 110 *Cannon Street, London, E.C.*
1872	Brockbank, William, *Brockhurst, Didsbury, near Manchester.*
1869	*Brogden, Alexander, M.P., 9 *Victoria Chambers, S. W.*
1869	*Brogden, Henry, *Hale Lodge, Altrincham, Manchester.*
1869	*Brogden, James, *Sea Bank House, Porthcawl, near Bridgend.*
1877	Bromley, Massey, 5 *Westminster Chambers, Victoria Street, S. W.*
1881	Brooke, Edward, *Edgerton, Huddersfield.*
1877	Brotherhood, Peter, 25 *Ladbrooke Gardens, Notting Hill, London, W.*

Elected Member	
1875	Brown, John, *The Hawthorns,* 3 *Lozells Road, Birmingham.*
1874	Brown, Joseph C., *Hazel Holm, Cleator,* viâ *Carnforth.*
1872	Brown, Richard, *Kensal Tower, Ayr, N.B.*
1873	Brown, Thomas Forster, *Cardiff.*
1881	Brownhill, Wm., Jun., *Birchill's Hall Iron Company, Walsall.*
1880	Bruce, John, 13 *Ainslie Place, Edinburgh.*
1872	Brunlees, James, 5 *Victoria Street, Westminster, S.W.*
1880	Brustlein, H. A., *Unieux, France.*
1876	Buchanan, A., *Handyside & Co., Limited, Derby.*
1881	Buckton, Walter, *Well House Foundry, Leeds.*
1872	Bull, James, *The Brampton, Newcastle-under-Lyne.*
1874	Bullen, Mark W., *Barnard Castle.*
1872	Bullivant, W. M., 12 *Mark Lane, London, E.C.*
1882	Bunter, James C., *Anderston Foundry, Glasgow.*
1870	Burden, James A., *Troy, New York, U.S.A.*
1881	Burn, R. Scott, *Oak Lea, Edgeley Road, near Stockport.*
1873	Burns-Lindow, J. L., *Whitehaven.*
1875	Burnup, J. M., 127 *Leadenhall Street, London, E.C.*
1876	Burridge, Stephen, *Atlas Steel and Iron Works, Sheffield.*
1881	Burrows, Ernest J., *West Cumberland Works, Workington.*
1877	Burrows, James, *Anderson Hall, Chorley, Lancashire.*
1880	Bush, George, *Georgenympton, South Molton, North Devon.*
1877	Butler, Ambrose Edmund, *Kirkstall Forge, Leeds.*
1872	Butler, Edmund, *Kirkstall Forge, Leeds.*

Elected Member	
1876	Butler, Isaac, *Somerset House, Swansea.*
1874	Butler, Jacob, 5 *Rowington Terrace, Handsworth, Birmingham.*
1874	Butler, John Theobald, *Roseberry Steel Works, Middlesbro'.*
1882	Butlin, Wm., *Irthlingborough Iron Works, Wellingborough.*
1872	Byers, J. S., *Stockton-on-Tees.*
1874	Byrne, Samuel Henry, *The Farre Close, Brighouse, Yorkshire.*
1872	Cadell, Henry, *Bridgeness Iron Works, Bo'ness, N.B.*
1877	Campbell, Daniel, 3 *Westminster Chambers, London, S.W.*
1873	Campbell, David, *Milton Iron and Tin Plate Works, Motherwell.*
1869	*Carbutt, E. Hamer, M.P., 19 *Hyde Park Gardens, W., and Llanwern House, Monmouth.*
1878	Carmont, William Haselwood, *Mansfield Chambers, St. Ann's Square, Manchester.*
1879	Carnegie, A., 57 *Broadway, New York, U.S.A.*
1882	Carr, Mark W., 4 *Woburn Place, London.*
1871	Carrington, Arthur, *Wingerworth Iron Works, Chesterfield.*
1881	Carruthers, Ben., *Worsbro' Park, Barnsley.*
1880	Carson, W., *Egremont, Cheshire.*
1872	Cassels, Jno. R., *Glasgow Iron Works, Glasgow.*
1871	Cassels, Robert, 168 *St. Vincent Street, Glasgow.*
1877	Casson, Richard Smith, *Round Oak Iron Works, Brierley Hill.*
1882	Cavendish, Lord Edward, M.P., *Chatsworth and Holker Hall.*
1876	Chambers, A. M., *Thorncliffe Iron Works, Sheffield.*
1872	Chapman, Henry, 113 *Victoria St., Westminster, S.W., and* 10 *Rue Laffitte, Paris.*
1874	Chapman, J. G., *Middleton St. George, Darlington.*

Elected Member	
1882	Chapman, John G., Jun., *Tower Hill, Middleton-One-Row, Darlington.*
1877	Chatwood, Samuel, *Bolton, Lancashire.*
1878	Chaytor, Hugh, *Coatham, Redcar.*
1872	Cheesman, Wm. T., *Hartlepool.*
1882	Church, Richard F., M.I.C.E., 1 *Victoria Street, Westminster.*
1877	Clapham, Henry, *Jesmond Cottage, Newcastle-on-Tyne.*
1870	Claye, S. John. *Manor House Works, near Derby.*
1874	Cleghorn, John, *Spring Gardens, London, S.W.*
1882	Cleminson, Jas., 7 *Westminster Chambers, London, S.W.*
1869	*Cliff, Joseph, *Frodingham Iron Works, Brigg, Lincolnshire.*
1882	Cliff, Wm. D., *Wortley, Leeds.*
1875	Clive, Robert, *Clanway Colliery and Iron Works, Tunstall, Staffordshire.*
1881	Closson, Prosper, 48 *Rue Laffitte, Paris.*
1877	Clover, R., *Continental Steel Works, Sheffield.*
1879	Cochrane, Alfred O., *Coatham, Redcar.*
1869	*Cochrane, Charles, *The Grange, near Stourbridge.*
1871	Cockburn, William, *Huntcliffe House, Saltburn-by-the-Sea.*
1882	Cole, Chas., *Brierley House, Brierley Hill.*
1870	Colquhoun, James, *Tredegar Iron Works, Tredegar, Monmouthshire.*
1881	Colquhoun, James, Jun., *Tredegar Iron Works, Tredegar, Monmouthshire.*
1878	Coltman, Huram, *Park Crescent, Portland Place, W.*
1877	Colver, Robert, *Continental Steel Works, Sheffield.*
1880	Colville, John, *Motherwell, N.B.*
1879	Cook, Joseph, Jun., *Washington, County Durham.*

Elected Member	
1880	Cooke, John, *Tinsley Steel and Iron Works, Sheffield.*
1870	Cooke, William, 58 *Earl Marshall Road, Pitsmoor, Sheffield.*
1874	Cooper, Arthur, *North Eastern Steel Co., Royal Exchange, Middlesbro'.*
1882	Cooper, Joseph, *Workington.*
1880	Cooper, Leonard, *Park Row, Leeds.*
1873	Copeland, Charles J., *Barrow-in-Furness.*
1879	Copestake, Sampson, *Burgess Hill, Sussex.*
1882	Corner, Edward, *Esk Hall, Sleights, Whitby.*
1881	Corner, James Robertson, *Workington Hematite Steel and Iron Works, Workington.*
1880	Corner, John, *Kingston Villa, Sydenham Park, S.E.*
1879	Cornish, Henry John, 2 *White Lion Court, Cornhill, E.C.*
1882	Cosgrove, John, *Edgbaston, Birmingham.*
1881	Coste, J. L. N., *Netherfield, Park Hill Road, Croydon.*
1881	Coste, M. E., *Netherfield, Park Hill Road, Croydon.*
1876	Coventry, J., 34 *Linnet Lane, Sefton Park, Liverpool.*
1878	Cowan, Alex. Bertram, *Tudhoe Iron Works, Spennymoor.*
1874	Coward, Edward, *Heaton Mersey, Manchester.*
1870	Cowper, Charles Edward, 6 *Great George Street, Westminster, S.W.*
1869	*Cowper, E. A., 6 *Great George Street, Westminster, S.W.*
1877	Coxon, Samuel B., *Usworth Hall, Washington, County Durham.*
1869	*Crampton, Thomas R., 4 *Victoria Street, Westminster, S.W.*
1880	Craven, T. F., *Craven Bros. & Co., Darnall, Sheffield.*
1869	*Crawshay, W. T., *Vaynor, Merthyr Tydvil.*
1876	Crippin, Edwd. Frederick, *Brynn Hall Collieries, near Wigan.*

Elected Member	
1872	Criswick, Theophilus, 8 *Gore Terrace, Swansea.*
1880	Croasdell, S., *Spring Bank, North Side, Workington.*
1869	*Crompton, George, *Stanton Iron Works, Nottingham.*
1877	Crompton, R. E. B., 4 *Mansion House Buildings, London, E.C.*
1880	Crookston, A. W., 19 *Wellington Street, Glasgow.*
1878	Croom, James, *Broughton Iron Works, Manchester.*
1869	*Crossley, William, 153 *Queen Street, Glasgow.*
1875	Crowther, Clement, *Stour Vale Iron Works, Kidderminster.*
1881	Crum, John, *Lowther Hematite Iron Works, Workington.*
1869	*Cuninghame, John, 127 *St. Vincent Street, Glasgow.*
1876	Cuninghame, J. C., *Craigends, Johnstone, N.B.*
1876	Cunliffe, Richard, *Broughton Iron Works, Manchester.*
1869	*Currey, William, 14 *Great George Street, Westminster, S.W.*
1882	Daelen, R. M., *Hohenzollernstrasse, Düsseldorf.*
1872	Daglish, Robert, *Aston Hall, near Preston Brook, Cheshire.*
1869	*Dale, David, *West Lodge, Darlington.*
1881	Dalglish, Richard, *The Limes, Asfordley, Melton Mowbray.*
1873	D'Allemagne, Guillaume, *Sclessin, Liége, Belgium,*
1874	D'Andrimont, Julien, *Liége, Belgium.*
1882	Danks, Samuel, *Hadley Park, near Wellington, Salop.*
1880	Darby, J. H., *Brymbo Iron Works, near Wrexham.*
1873	Darling, William L., *Dowlais.*
1870	Davey, George H., *Baglan, near Neath, Glamorganshire.*

Elected Member	
1880	Davey, Henry, *Sun Foundry, Leeds.*
1874	Davies, Geo. William, *Care of Charles Cochrane, The Grange, Stourbridge.*
1882	Davies, William H., *Pontymister House, Pontymister, Mon.*
1875	Davis, Alfred, *Parliament Mansions, Victoria Street, London, S.W.*
1878	Davis, E. Prosser, *Awsworth Iron Works, Ilkeston, near Nottingham.*
1882	Davis, John B., *Bilbao, Spain.*
1878	Davy, Walter Scott, *Park Iron Works, Sheffield.*
1869	*Dawes, George, *Elsecar Iron Works, Barnsley.*
1872	Day, St. John Vincent, 115 *St. Vincent Street, Glasgow.*
1874	Deby, Julien, 75 *Holland Road, South Kensington, S.W.*
1878	De Lara, Alfred O., *Marchiénne au Pont, Belgium.*
1879	Delorme, I., *Société de Montain à Outreau, Pas-de-Calais.*
1880	Denholm, G., Sen., *St. George's Iron Works, Manchester.*
1881	Denne, Thos. M., *Canal Iron Works, Hatcham.*
1880	Dennis, W. F., 101 *Leadenhall Street, London, E.C.*
1881	Denny, William, *Bellfield, Dumbarton, N.B.*
1880	Dering, G. E., *Lockleys, Welwyn, Herts.*
1874	Desbrières, P., 96 *Rue d'Amsterdam, Paris.*
1869	*Devonshire, The Duke of, K.G., *Holker Hall, Grange, Lancashire.*
1879	Dick, G. Alex., 110 *Cannon Street, London, E.C.*
1876	Dickenson, Samuel, *Newbridge, Wolverhampton.*
1881	Dixon, A. A., 24 *Queen Victoria Street, London, E.C.*
1880	Dixon, D. W., *Brotton Mines, Saltburn-by-the-Sea.*
1882	Dixon, Henry E., *Elm Bank, Darlington.*

Elected Member	
1882	Dixon, John, 1 *Lawrence Pountney Hill, London, E.C.*
1874	Dixon, Joseph, *Sheffield Steel and Iron Works, Attercliffe, Sheffield.*
1869	*Dixon, Raylton, *Cleveland Iron Shipyard, Middlesbrough.*
1869	*Dobbs, Charles James, *Post Office Chambers, Middlesbrough.*
1873	Dobbs, Henry, *North Ormesby, Middlesbrough.*
1869	*Dodds, Joseph, M.P., *Stockton-on-Tees.*
1872	Dodds, Matthew B., *Stockton-on-Tees.*
1874	Dorman, A. J., *Middlesbrough.*
1870	Douglas, C. P., *Parliament Street, Consett, Durham.*
1875	Dove, George, Jun., *Redbourn Hill Iron Works, Frodingham, Lincolnshire.*
1877	Downar, Geo. F., *Chapel Road, Bexley Heath, Kent.*
1869	*Downey, Alfred C., *Coatham Iron Works, Middlesbrough.*
1877	Downie, Alexander, *The Ashes, Stanhope, Weardale.*
1881	Downing, Samuel, *Richmond Iron Works, West Bromwich.*
1871	Dudley, The Earl of, *The Priory, Dudley.*
1869	*Dunlop, Colin Robert, *Glasgow.*
1875	Dunnachie, James, *Glenboig, near Coatbridge, N.B.*
1877	Du Pre, Francis Baring, *Tudhoe Iron Works, Spennymoor.*
1875	Durfee, Wm. F., 89 *Courtland Street, Bridgeport, Connecticut, U.S.A.*
1881	Durham, The Earl of, *Lambton Castle, Fence Houses, Co. Durham.*
1876	Durieux, Aimé, 11 *Rue des Saussails, Paris.*
1875	Dyson, George, *Middlesbrough.*
1880	Eadie, James, *Clydesdale Tube Works, Rutherglen.*

Elected Member	
1882	Eagland, W., *West Yorkshire Iron Works, Ardsley.*
1882	Easton, Edward, *Delahay Street, Westminster, S.W.*
1875	Eddy, Jas. R., *Carlton Grange, Skipton, Yorkshire.*
1880	Edge, John H., *Coalport Works, Shifnal, Salop.*
1879	Ehlers, W., *Cartagena, Spain.*
1880	Ehrhardt, B., *Cainsdorf, Saxony.*
1877	Elliot, Sir George, Bart., M.P., *Great George Street, London, S.W.*
1875	Ellis, J. D., *Atlas Works, Sheffield.*
1872	Ellis, Thomas, *Coatbridge, N.B.*
1879	Ellison, John, *Ebbw Vale Works, Monmouthshire.*
1878	Escalle, Pierre, *Tamaris, Gard, France.*
1874	Euchene, Albert, 140 *Avenue de Choisy, Paris.*
1882	Evans, Christmas, *Dinas Main Colliery, Wales.*
1873	Evans, David, *Rhymney Iron Works, Monmouthshire.*
1881	Evans, J. Campbell, 25 *Russell Road, Kensington, London, W.*
1878	Evans, Richard, *Consett Iron Works, Consett, Durham.*
1873	Evans, Silas, 9 *Victoria Chambers, Belfast.*
1869	*Evans, William, *Bowling Iron Works, Bradford, Yorkshire.*
1882	Evans, William, *Llwyneillyn House, Merthyr Tydfil, Glamorganshire.*
1875	Evers-Swindell, J. S., *Clent House, Stourbridge.*
1869	*Farley, Reuben, *Summit Foundry, West Bromwich.*
1869	*Farnworth, William, *Swinden Iron Works, Dudley.*
1877	Faustman, E., *Millsands Rolling Mills, Sheffield.*

Elected Member
1872 Faviell, Henry F.,
St. John's Chambers, Walbrook, London, E.C.
1870 Ferrie, William,
Monkland Iron Works, Glasgow.
1869 *Firmstone, H. O.,
Leys Iron Works, Stourbridge.
1882 Firth, Lewis J.,
Norfolk Works, Sheffield.
1881 Fischer, M. F.,
Hagen, Westphalia.
1870 Fisher, E. K.,
Market Harborough.
1880 Fitzmaurice, L. J.,
Cwm Avon, Taibach, Glamorganshire.
1881 Flather, William T.,
Love Street Steel Works, Sheffield.
1877 Fletcher, W.,
Brigham Hill, viâ *Carlisle.*
1869 *Fletcher, William,
Cartgate, Whitehaven.
1880 Flower, P. W.,
Neath, Glamorganshire.
1872 Forester, W. H.,
Sketty Park, Swansea.
1880 Foster, H. Le Neve,
Mossend Iron and Steel Works, Holytown Station, N.B.
1869 *Foster, W. O., M.P.,
Stourbridge Iron Works, Stourbridge.
1879 Forsyth, Robert,
North Chicago Rolling Mills, Chicago, U.S.A.
1874 Fossick, William G.,
86 *Cannon Street, London, E.C.*
1879 Fould, Alphonse,
Pompey, Meurthe-et-Moselle, France.
1882 Fowler, Edmund,
Birmingham Wagon Company.
1871 Fox, Samuel,
Stocksbridge, near Sheffield.
1877 Fox, Sampson,
Leeds Forge Company, Armley, Leeds.
1880 France, W.,
Loftus, Saltburn-by-the-Sea, Yorks.
1882 Freir, William E.,
44*a Cannon Street, London, E.C.*
1873 French, William
59 *St. Vincent Street, Glasgow.*
1881 Frey, C. A. V.,
I. Maximilianstrasse 2, Vienna, Austria.

Elected Member	
1882	Fromm, E., *Maximilianhütte, Regensberg, Bavaria.*
1879	Fry, John E., *South Saint Louis, Mo., U.S.A.*
1869	*Fry, Theodore, M.P., *Darlington.*
1875	Furuhjelm, E. H., *Helsingfors, Finland.*
1882	Galloway, Arthur Walton, *Knott Mill Iron Works, Manchester.*
1870	Galloway, Charles John, *Knott Mill Iron Works, Manchester.*
1875	Galloway, John, Jun., *Knott Mill Iron Works, Manchester.*
1882	Galton, Captain D., C.B., D.C.L., F.R.S., 12 *Chester Place, Grosvenor Place, London.*
1876	Garforth, W. E., *Lordsfield Colliery, Ashton-under-Lyne.*
1879	Gargan, Baron de, *Hayange, Alsace-Lorraine, Germany.*
1875	Gautier, Ferdinand, 90 *Avenue Victor Hugo, Paris.*
1878	Gent, Joseph, *Victoria Iron Works, Salford.*
1875	Giesbers, Frederick, 22 *Hartham Road, Camden Road, London, N.*
1875	Gilchrist, P. C., 172 *Palace Chambers, Bridge Street, Westminster, S.W.*
1869	*Gilkes, Edgar, *Tees Side Iron Works, Middlesbrough.*
1869	*Gilkes, Gilbert, *Ivy Garth, Kendal.*
1870	Gill, William, 53 *Gracechurch Street, London, E.C.*
1881	Gill, William, *Oroconera Iron Company, Bilbao, Spain.*
1872	Gillott, Thomas, *Farnley, near Leeds.*
1872	Gilmour, Allan, *Woodend, Kilmarnock, N.B.*
1869	*Gjers, John, *Ayresome Iron Works, Middlesbrough.*
1882	Gjers, Lawrence F., 3 *Southfield Villas, Middlesbrough.*

Elected Member	
1871	Goddard, Jno. H., *Lane End Iron Works, Longton, Staffordshire.*
1869	*Godfrey, Samuel, *Middlesbrough Iron Works, Middlesbrough.*
1879	Goldsworthy, R. B., *Hulme, Manchester.*
1871	Goldwyer, John E., *Holme Bank, Tyersall, near Bradford.*
1881	Gordon, Andrew, *Cransley Iron Works, Kettering.*
1873	Gordon, Joseph G., *Queen Anne's Mansions, S.W.*
1880	Gössell, O., Jun., 110 *Cannon Street, London, E.C.*
1882	Gotto, Edward, 17B *Great George Street, Westminster, S.W.*
1878	Gottschalk, Alexandre, 17 *Rue Laffitte, Paris.*
1872	Gowen, Franklin B., 227 *South Fourth Street, Philadelphia, U.S.A.*
1869	*Granville, Earl, K.G., *Carlton House Terrace, London, S.W.*
1869	*Grazebrooke, Henry, Jun., *Stourbridge Iron Works, Stourbridge.*
1871	Greck, P., 56 *Hereford Road, Bayswater, London.*
1881	Green, John, *Tin Plate Works, Abercarn, Mon.*
1882	Greene, Robert R., *Highfield, Dublin.*
1875	Gregory, T. Currie, 52 *Queen Victoria Street, London, E.C.*
1875	Greig, David, *Steam Plough Works, Leeds.*
1870	Greig, John, *Coltness, Newmains, N.B.*
1876	Greiner, A., *Société John Cockerell, Seraing, Belgium.*
1873	Grice, Edwin J., *Newport, Monmouthshire.*
1874	Griffiths, N. R., *Wrexham.*
1869	*Griffiths, William, *Derwent Tin Plate Works, Workington.*
1872	Griswold, Chester, 56 *Broadway, New York, U.S.A.*
1869	*Grove, Edwin, *Brendon View, Stow Park, Newport, Monmouthshire.*

Elected Member	
1879	Gruson, H., *Buckau, Magdeburg, Germany.*
1875	Guest, Josiah, *Victoria Foundry, West Bromwich.*
1882	Guilleaime, Emile, *Carlswerk, Mulheim-on-Rhine, Germany.*
1880	Guilliaume, F. C., 8 *Carlstrasse, Cologne, Germany.*
1875	Gunther, William, *Central Engineering Works, Oldham.*
1878	Haarmann, August, *Osnabrück Iron and Steel Works, Osnabrück, Prussia.*
1874	Hadfield, Robert, *Attercliffe, Sheffield.*
1875	Hagerman, J. J., *Milwaukee Iron Works, Wisconsin, U.S.A.*
1870	Haggie, Peter, *Gateshead-on-Tyne.*
1879	Hald, J. F. D., 27 *Great Winchester Street, E.C.*
1878	Hall, J. F., *Brightside Works, Sheffield.*
1872	Hall, William F., *Haswell Colliery, Fence Houses, Durham.*
1873	Hallam, Thomas, *Grove Hill, Middlesbrough.*
1879	Hallopeau, P. F. A., 24 *Rue de Lyon, Paris.*
1873	Halpin, Druitt, 9 *Victoria Chambers, London, S.W.*
1881	Hammond, Robert, 110 *Cannon Street, London, E.C.*
1870	Hampton, Thomas, *Phœnix Bessemer Steel Works, The Ickles, near Sheffield.*
1882	Hannah, Joseph, *Castle View, Carlisle.*
1880	Hannay, G. Kerr, *Hill Fort, Ulverston.*
1875	Hansell, R. B., 90 *Hanover Street, Sheffield.*
1879	Hansen, A., 13 *Westenhellweg, Dortmund, Westphalia.*
1869	*Hanson, William, *Newport Iron Works, Middlesbrough.*
1869	*Hardeman, Charles H., *The Brampton, Newcastle-under-Lyne.*

Elected Member	
1875	Harding, George, *Biddulph Iron Works, Stoke-on-Trent.*
1875	Harding, Joshua, *Norton Iron Works, near Burslem, Staffordshire.*
1881	Harmet, Henri, *Denain, Nord, France.*
1876	Harrison, G. K., *Hagley, near Stourbridge.*
1874	Harrison, James, *Askam-in-Furness.*
1878	Harrison, Richard, C.E., *Grainger Street West, Newcastle-on-Tyne.*
1876	Harrison, Richard M., *Workington.*
1871	Harrison, Thomas E., *Whitburn, Sunderland.*
1882	Harrison, Wm. B., *Cyclops Iron Works, Walsall.*
1877	Hart, John, *New Exchange Buildings, Middlesbrough.*
1876	Hartley, Jno., *Newhall Steel Wire Mills, Attercliffe, Sheffield.*
1869	*Hartley, John, *Tong Castle, Shifnal, Salop.*
1881	Hartmann, Jean, *Longwy, Moselle, France.*
1876	Harvey, Wm., *Netherton House, Wishaw, near Glasgow.*
1882	Haswell, Chas. J. F., *Theresianumgasse*, 10, *Vienna.*
1875	Hatton, George, *Broadwater Tin Plate Works, Kidderminster.*
1879	Hatton, William, *Hill Grove, Kidderminster.*
1876	Hawdon, William, *Newport Iron Works, Middlesbrough.*
1882	Hawksley, Chas., 30 *Great George Street, Westminster, S. W.*
1882	Hawksley, Thos., F.R.S., 30 *Great George Street, Westminster, S. W.*
1882	Hay, Alexander S., *Nettlestone, South Hampstead.*
1869	*Head, Charles A., *Teesdale Iron Works, Stockton-on-Tees.*
1882	Head, H. E., *Landore Steel Works, Swansea.*
1869	*Head, Jeremiah, *Newport Rolling Mills, Middlesbrough.*

Elected Member	
1881	Heath, A. H., *Biddulph Grange, Congleton.*
1873	Heath, James, 41 *Portman Square, London, W.*
1869	*Heath, Robert, *Biddulph Iron Works, Stoke-on-Trent.*
1872	Heath, Robert, Jun., *Biddulph Iron Works, Stoke-on-Trent.*
1875	Heathfield, E., 158 *Leadenhall Street, London, E.C.*
1875	Heathfield, R., *Edgbaston Hall, Birmingham.*
1880	Hedley, Robt., *Tudhoe Iron Works, Spennymoor.*
1873	Hedley, Thomas, *Newcastle-on-Tyne.*
1881	Helme, Richard, *Walthamstow, Essex.*
1878	Helmholtz, Otto, *Linden vor Hanover, Germany.*
1877	Helson, Cyriaque, *Ingenieur-Directeur des Etablissements Metallurgiques de MM. Vardy et Benech, Savona, Italy.*
1877	Helson, Michel, *Hautmont, France.*
1873	Henderson, Robert, *Drumpellier Iron Works, Coatbridge, N.B.*
1880	Henriquez, C. Q., 5 *Westminster Chambers, London, S.W.*
1874	Hesketh, Thomas, *Summerfield, Bolton, Lancashire.*
1870	Hewett, Edward E., *High Court, High Street, Sheffield.*
1869	*Hewlett, Alfred, *Kirkless Hall Iron Works, Wigan.*
1873	Hewlett, W. H., *Wigan Coal and Iron Company, Wigan.*
1879	Heywood, H. H., *Cardiff.*
1879	Hick, John, M.P., *Mytton Hall, Whalley, Blackburn.*
1879	Hickman, A., *Spring Vale Furnaces, Wolverhampton.*
1881	Higginbottom, James, *Seel Street, Liverpool.*
1879	Higson, Jacob, 68 *New Bridge Lane, Stockport.*

Elected Member	
1869	*Hill, Alfred C., *Lackenby Iron Works, Middlesbrough.*
1881	Hill, A. William, *Hartlepool.*
1878	Hill, Francis, *Stocksbridge, near Sheffield.*
1873	Hill, Lawrence, 59 *St. Vincent Street, Glasgow.*
1874	Hilton, Franklin, 9 *St. John's Terrace, Middlesbro'.*
1870	Hirst, Thomas, *Dowlais, Glamorganshire.*
1874	Hobson, Henry, *Parton Hematite Iron Works, Parton, Cumberland.*
1879	Hobson, J. F., *Washington, County Durham.*
1873	Hodgetts, Alfred, *St. Bees,* viâ *Carnforth.*
1878	Hodgson, John, *Darlington Forge, Darlington.*
1873	Hodgson, John Lee, *Apsley Terrace, Heaton-Chapel, Stockport.*
1880	Hoesch, A., *Dortmund, Westphalia.*
1869	*Holcroft, James, *Portfield Iron Works, Tipton.*
1874	Holland, C. B., *Ebbw Vale Works, Newport, Mon.*
1873	Hollingsworth, A. T., 36 *Bedford Street, Strand, W.C.*
1880	Hollis, H. W., *Butterley Iron Works, Alfreton.*
1876	Holste, Carl, 21 *Great St. Helen's, London, E.C.*
1876	Holt, Henry Percy, *Fairlea, Palatine Road, Didsbury, Manchester.*
1880	Holt, W. L., 1 *Pelham Place, London, S.W.*
1871	Homer, Charles J., *Stoke-upon-Trent.*
1873	Hopkinson, John, *Grove Hill, Oxford Road, Manchester.*
1874	Hornung, J. P., *Grove Hill, Middlesbrough.*
1879	Horsfall, G. H., Jun., *Larkfield, Toxteth Park, Liverpool.*
1876	Horsfall, Hodgson, 180 *Bedford Street South, Liverpool.*

Elected Member	
1882	Horton, John R., *Buckley Grange, Shifnal.*
1869	*Horton, Thomas E., *Buckley Grange, Shifnal, Salop.*
1870	Hosgood, Thomas H., *Bute Villa, Aberdare.*
1872	Hosking, Richard, *Dalton-in-Furness.*
1873	Houghton, John, *The Beeches, Moore, near Warrington.*
1880	Houldsworth, Jas., 36 *Queen's Gate, London.*
1882	Houldsworth, W. J., 36 *Queen's Gate, London.*
1881	Howard, James, M.P., *Clapham Park, Bedfordshire.*
1869	*Howson, R., *Exchange Place, Middlesbrough.*
1878	Hoysradt, Jacob W., *Hudson, New York, U.S.A.*
1880	Huart, F., *Longwy, Moselle, France.*
1880	Huart, H., *Longwy, Moselle, France.*
1880	Hudspeth, W., *Haltwhistle, Northumberland.*
1882	Huggett, J. A., *Nail Works, Wandsworth Road, London, S.W.*
1877	Hughes, Arthur D., *Care of F. Taylor,* 35 *Queen Victoria Street, London, E.C.*
1878	Hughes, John, *Care of F. Taylor,* 35 *Queen Victoria Street, London, E.C.*
1882	Hughes, Wm., 19 *Lionel Street, Birmingham.*
1882	Hulse, Wm. W., *Ordsal Tool Works, Regent Bridge, Salford, Manchester.*
1872	Humphreys, A. W., 42 *Pine Street, New York, U.S.A.*
1871	Hunt, James P., *Corngreaves Iron Works, near Birmingham.*
1882	Hunt, John, *Managing Director of the Hallamshire Steel and File Co., Limited, Sheffield.*
1870	Hunter, Charles L., 2 *Belgrave Terrace, Roath, Cardiff.*
1869	*Hunter, James, *Coltness Iron Works, Newmains, N.B.*

Elected Member

1869 *Hunter, John,
Dalmellington Iron Works, Ayr, N.B.
1881 Huntington, Alfred Kirby,
King's College, London, W.C.
1876 Hurll, Jno.,
68 *Bath Street, Glasgow.*
1882 Hutchinson, Thomas C.,
Hilda House, Middlesbro'.
1877 Hutchinson, William,
54 *King William Street, London, E.C.*
1876 Hutton, Robert,
Batts Foundry, Whitby.
1869 *Hyde, General, R.E.,
India Office, Westminster, S.W.

1875 Ianson, James,
Fairfield House, Darlington.
1869 *Ianson, J. C.,
Rise Carr Rolling Mills, Darlington.
1876 Ingham, William P.,
Middlesbrough.
1874 Ireland, Jonathan,
Edward Street, Broughton Lane, Manchester.

1881 Jackson, John,
Stubben Edge, Chesterfield.
1873 Jackson, W. F.,
Bowling Iron Works, Bradford, Yorkshire.
1881 Jacobi, Hugo,
Gütehoffnungshütte, Westphalia, Germany.
1869 *Jaffrey, G. W.,
Westland Terrace, 17 *Robertson Street, Greenock.*
1873 James, Phineas,
Abercarn Estate Office, Abercarn, Newport, Mon.
1880 James, Richard,
H. M.'s Dockyard, Chatham.
1872 James, Thomas,
Redcar Iron Works, Redcar.
1875 Jarrett, Daniel,
Ebbw Vale Works, Newport, Mon.
1869 *Jayne, Basil,
Tillery Collieries, Abertillery, Mon.
1877 Jeans, J. S.,
Victoria Mansions, Victoria Street, S.W.
1879 Jefferies, J. R.,
Ipswich.

Elected Member	
1869	*Jeffreys, E., *Lipton Lodge, Leeds.*
1876	Jenkins, A. T., *Masbro' Boiler Works, Rotherham.*
1872	Jenkins, James G., 33 *Renfield Street, Glasgow.*
1869	*Jenkins, Sir J. J., *The Grange, Swansea.*
1869	*Jenkins, William, *Consett Iron Works, Consett, County Durham.*
1874	Jenkins, William, *Dowlais Iron Works, Dowlais.*
1882	Jennings, Charles James Pascoe, *South Bank, Yorkshire.*
1875	Jennings, James, *Marton Grove House, Middlesbrough.*
1879	John, William, 2 *White Lion Court, Cornhill, London, E.C.*
1871	Johnson, Richard S., *Sherburn Hall, Durham.*
1871	Johnson, Thewlis, *Bradford Iron Works, Manchester.*
1873	Johnson, Walter, 7 *Zetland Road, Middlesbrough.*
1875	Johnson, W. H., 26 *Lever Street, Manchester.*
1880	Johnston, James, *St. George's Chambers,* 98 *Albert Square, Manchester.*
1881	Jonas, Joseph, *Continental Steel Works, Sheffield.*
1882	Jones, Alfred W., *Dashwood House, New Broad Street, E.C.*
1870	Jones, Benjamin, *Dowlais Iron Works, Dowlais.*
1878	Jones, Daniel N., *Cambria Iron Works, Johnstown, Pa., U.S.A.*
1881	Jones, Edwin, 3 *Crooked Lane, King William Street, E.C.*
1869	*Jones, Edwin F., *Normanby Iron Works, Middlesbrough.*
1878	Jones, Edwin While, *Cleveland Steel Works, South Bank, Middlesbro'.*
1874	Jones, Ephraim A., *Ayrton Rolling Mills, Middlesbrough.*
1872	Jones, Frederick F.
1882	Jones, Irvonwy, *Rhyader House, Eaton Terrace, Swansea.*

Elected Member	
1870	Jones, John, *Dowlais Iron Works, Dowlais.*
1881	Jones, Joseph, *Corrugated Iron Works, Wolverhampton.*
1875	Jones, Wm., *Cyfarthfa, Merthyr Tydfil.*
1881	Jones, Wm. E., 3 *Crooked Lane, King William Street, E.C.*
1881	Jones, Wm. Richard, 48 *Fifth Avenue, Pittsburg, U.S.A.*
1874	Jordan, Sampson, 5 *Rue Viètte, Quartier Monceaux, Paris.*
1875	Jordan, Thomas, *Dunkirk Iron Works, West Bromwich.*
1869	*Joseph, David, *Rocklease, Durdham Down, Bristol.*
1878	Jouraffsky, Demetrius, *St. Petersburg, Russia.*
1882	Jowitt, Thomas W., *Scotia Steel Works, Sheffield.*
1879	Justice, P. M., 53 *Southampton Buildings, Chancery Lane, London.*
1881	Justice, Philip S., 53 *Southampton Buildings, Chancery Lane, London.*
1880	Kam, J. H. J., *Delfshaven, Holland.*
1880	Kam, S. J. J., *Delfshaven, Holland.*
1874	Kellett, William, 24 *King Street, Wigan.*
1874	Kennedy, Myles, *Ulverston.*
1881	Kenrick, Geo. H., *Maple Bank, Church Road, Birmingham.*
1873	Kershaw, Wm. A., *Barrow-in-Furness.*
1869	*Kirk, Henry, *Workington.*
1874	Kirk, Peter, *Mossbay Iron Works, Workington.*
1869	*Kirkconel, John, *Cleator Moor,* viâ *Carnforth.*
1872	Kislanski, W., *Lilpop, Raw, et Loewenstein, Warsaw, Russia.*
1881	Kitching, John, *Elm Field, Darlington.*

Elected Member	
1869	*Kitson, James, Jun., *Monkbridge Iron Works, Leeds.*
1879	Koch, Charles, *St. Chamond, Loire, France.*
1878	Koch, W. E., 107 *Philbeach Gardens, S. Kensington, S.W.*
1880	Kochs, W. E., *Cyfarthfa Iron Works, Merthyr Tydvil.*
1875	Kolokoltzoff, Rear-Admiral, *Obouchoff Steel Works, St. Petersburg, Russia.*
1880	Kupelwieser, Paul, *Witkowitz, Austria.*
1872	Laidlaw, David, *East Milton Street, Glasgow.*
1873	Laidlaw, Robert, *East Milton Street, Glasgow.*
1874	Laing, James, *Sunderland.*
1873	Lan, Charles, *Ecole des Mines, Paris.*
1874	Lancaster, John, *Bilton Grange, Rugby.*
1874	Lancaster, Joshua, *Rhewl House, Mostyn, Flintshire.*
1880	Lancaster, Samuel, *Blaina, South Wales.*
1872	Landale, Andrew, *Lochgelly Iron Works, Fifeshire.*
1881	Langdon, Wm., *Huelva, Spain.*
1877	Larsen, Jno. Daniel, 27 *Dalhousie Square, Calcutta.*
1876	Lawson, Arthur T., *Beech Grove House, Leeds.*
1870	Lawson, John, 5 *Auckland Hill, Lower Norwood, London.*
1869	*Laybourne, Richard, *Isca Foundry, Newport, Mon.*
1873	Ledger, Joseph, *Castellette, Keswick.*
1874	Lee, William, 110 *Cannon Street, London, E.C.*
1873	Lees, Eli, 102 *Lancaster Gate, London, W.*
1876	Leeuw, F. de, *Antwerp, Belgium.*

Elected Member	
1879	Leigh, J., *Brimmington Hall, Stockport.*
1880	Leith, A. J., *Chicago, Illinois, U.S.A.*
1882	Lennard, John M., *Middlesbro'-on-Tees.*
1881	Leo, L., *Bochum, Westphalia.*
1879	Lester, John, 4 *Old Park Terrace, Wednesbury.*
1878	Lester, John Nicholls, *Bradford Iron Works, Walsall.*
1878	Lester, Richard, 8 *Crankhall Lane, Wednesbury.*
1870	Leveson-Gower, Hon. E. F., M.P., 14 *South Audley Street, London.*
1870	Levick, Frederick, *Cornhill Chambers, White Lion Court, E.C.*
1882	Lewis, Fred. E., 83 *Darlington Street, Wolverhampton.*
1869	*Lewis, H. W., *Treherbert, near Pontypridd.*
1881	Lewis, Henry, 129 *Hagley Road, Edgbaston, Birmingham.*
1870	Lewis, Lewis Thomas, *Neath, Glamorganshire.*
1882	Lewis, William B., 8 *Victoria Chambers, Westminster, S. W.*
1871	Lewis, William Thomas, *Mardy, Aberdare.*
1874	Lindheim, W. Von, *Lugeck,* 3, *Vienna.*
1874	Lindow, Jonas, *Ehen Hall, Cleator, Whitehaven.*
1881	Lindsay, Thos. S., 31 *Poultry, London, E.C.*
1882	Lithman, Jos. E., 17 *Fenchurch Street, London, E.C.*
1881	Little, George, *Messrs. Platt Brothers, Oldham.*
1880	Livesey, James, 9 *Victoria Chambers, London, S. W.*
1880	Ljungberg, E. J., *Falun, Sweden.*
1876	Llewellyn, F. W., *Shelton Bar Iron Works, Stoke-on-Trent.*
1869	*Lloyd, Francis H., *Wood Green, Wednesbury.*

Elected Member

1876 Lloyd, Jno.,
Priors Lee Hall, Shifnal, Salop.
1869 *Lloyd, Samuel,
The Farm, Sparkbrook, Birmingham.
1880 Lloyd, W. E.,
303 *Ickneild Port Road, Birmingham.*
1874 Lloyd, William Henry,
Hall Green, Wednesbury.
1869 *Lloyd, Wilson,
Mywood House, Wednesbury.
1875 Lones, Edward,
82 *Blake Street, Barrow-in-Furness.*
1875 Long, A. de Lande,
Stockton-on-Tees.
1871 Longridge, R. B.,
Yew Tree House, Tabley, near Knutsford.
1875 Longridge, R. C.,
Kibrie, Knutsford.
1869 *Longsdon, Alfred,
9 *New Broad Street, E.C.*
1880 Looker, P. S.,
43 *Finsbury Square, London, E.C.*
1880 Lorsbach, A.,
36 *Fynone Terrace, Swansea.*
1881 Louis, Henry,
Care of S. Louis, 10 *Cromwell Houses, Fellows Road, N.W.*
1874 Lowe, John E.,
2 *Lawrence Pountney Hill, London, E.C.*
1875 Lowood, John Grayson,
Ganister Works, Sheffield.
1876 Lueg, Carl,
Gütehoffnungshütte, Oberhausen, Westphalia.
1882 Lueg, C. H.,
Düsseldorf, Germany.
1876 Lürmann, F. (Engineer),
Osnabrück, Germany.

1880 Macco, H.,
Siegen, Germany.
1878 MacDonald, Archibald S. L.,
Middlesbrough.
1869 *Macfarlane, Walter,
Saracen Foundry, Glasgow.
1881 Macintyre, P.,
Solway Iron Works, Maryport.
1874 Mackenzie, H. M.,
Distington, Whitehaven.

Elected Member	
1879	Maclaran, R., *Dafin Tin Plate Works, Gilfig, Llanelly.*
1882	Maclean, Andrew H., 13 *Grosvenor Terrace, Glasgow.*
1873	Maclennan, Joseph, *Bilbao, Spain.*
1882	McNay, Thomas F., 41 *Parliament Street, S.W.*
1876	MacNay, William, *New Shildon, near Darlington.*
1881	Macnee, D., 2 *Westminster Chambers, London.*
1879	Main, Robert, *Carnbroe Iron Works, Coatbridge, near Glasgow.*
1879	Malo, Alberto, *Guanjuato, Mexico.*
1870	Manby, Cordy, *Dudley.*
1878	Marché, Ernest, 4 *Rue Neuve, Fontaine St. George, Paris.*
1880	Marcothy, Henri, *Duisburg, Hochfeld, Germany.*
1879	Margery, Jules, *Aachener Hütte, Rothe Erde, near Puy-la-Chapelle.*
1882	Marié, Marcos, 13A *Great George Street, Westminster, S.W.*
1869	*Markham, Charles, *Tapton House, Chesterfield.*
1879	Maroquin, A., *Couillet, near Charleroi, Belgium.*
1873	Marsh, T. E. M., *Engineer's Office, Hawthorn House, Bath.*
1881	Marsh, W. S., 34 *Grosvenor Place, Bath.*
1878	Marshall, David, *Glasgow Tube Works, Glasgow.*
1880	Marshall, F. H., *Ormesby Iron Works, Middlesbrough.*
1875	Marshall, R., *Caldergrove, Newton, near Glasgow.*
1876	Martélet, Mons., 56 *Rue de Provence, Paris.*
1879	Martell, B., 2 *White Lion Court, Cornhill, London.*
1882	Marten, Edward B., *Stourbridge.*
1869	*Marten, Henry John, *The Birches, Codsall, near Wolverhampton.*

Elected Member	
1873	Martin, A. H., *Dowlais, Glamorganshire.*
1871	Martin, Edward P., *Dowlais, Glamorganshire.*
1870	Mason, Thomas, 25 *Salthouse Road, Barrow-in-Furness.*
1878	Massenez, Joseph, *Hoerde, Westphalia.*
1880	Massey, W. H., *Twyford, Berks.*
1880	Massicks, Horace, *Askam Iron Works, Askam-in-Furness.*
1869	*Massicks, Thomas, *Millom Iron Works, Millom, Cumberland.*
1874	Maw, William Henry, 36 *Bedford Street, Strand, London, W.C.*
1881	Maybery, Joseph, *Oldcastle Tin Plate Works, Llanelly.*
1872	Maylor, John, *Churton Lodge, by Chester.*
1874	Maynard, George W., 24 *Cliff Street, New York, U.S.A.*
1869	*Maynard, H. N., 7 *Westminster Chambers, London, S.W.*
1881	McLellan, George S., *Clutha Steel Works, Glasgow.*
1871	M'Clelland, Andrew S., 104 *St. Vincent Street, Glasgow.*
1878	M'Creath, James, 95 *Bath Street, Glasgow.*
1881	M'Gregor, Josiah, *Crown Buildings,* 78 *Queen Victoria St., London, E.C.*
1872	M'Kerrow, Alexander, 5 *Victoria Street, Westminster, S.W.*
1874	M'Pherson, George, *Wednesbury Oak Iron Works, Tipton.*
1880	Melling, S., *Ince Forge Company, Wigan.*
1874	Mellon, Henry, *Brook Lea, Askam-in-Furness.*
1877	Menart, Jean Batiste, *Charleroi, Belgium.*
1878	Merritt, W. H., 34 *St. George Street, Toronto, Canada.*
1882	Miller, John F., *Vulcan Foundry, Coatbridge, N.B.*
1872	Millington, Samuel L., *Summerhill Iron Works, Tipton.*

Elected Member	
1875	Milner, Walter, *Whitecross Wire Works, Warrington.*
1870	Mitchell, Charles, *Walker, Newcastle-on-Tyne.*
1873	Mitchinson, H. S., *Bowling Iron Works, Bradford, Yorkshire.*
1870	Monks, F., *Brooklands, Warrington.*
1879	Montefiore, E. L., 118 *Rue de Grenelle, Paris.*
1873	Moon, Richard, Jun., *Penyvael, Llanymynech, near Oswestry.*
1881	Moore, Alfred, *Fitzroy Works, Euston Road, London, W.C.*
1876	Moore, Arthur, *Ida Wharf, Black Horse Bridge, Deptford, S.E.*
1882	Moore, William, *Santon Cottage, near Brigg.*
1875	Morel, Ernest, *Tilleul Rolling Mills, Maubeuge, France.*
1880	Morgan, C. H., *Worcester, Mass., U.S.A.*
1881	Morgan, James Henry, 124 *Narrow Street, Limehouse, London, E.*
1876	Morgan, John Walter, *Llanelly Iron Works, Llantrissant.*
1882	Morgan, Thomas, *Alliance, Ohio, U.S.A.*
1877	Morison, Arthur Duff, *Great Western Iron Works, Newnham, Gloucestershire.*
1876	Morison, D. P., 21 *Collingwood Street, Newcastle-on-Tyne.*
1882	Morris, Claude John, *The Mount, Altrincham.*
1881	Morris, Edw. S., *Pendawdd, Glamorganshire.*
1872	Morrison, H. M., *West Gorton, Manchester.*
1874	Morrison, Martin, *Middlesbrough.*
1873	Morton, E. H., *Glenbrook, Cearn's Road, Oxton, Cheshire.*
1879	Morton, James, *Palmerston Buildings, Greenock.*
1879	Morton, James, *Langloan Iron Works, Coatbridge, N.B.*
1873	Morton, Thomas, *Motherwell, N.B.*

Elected Member	
1875	Mosley, Paget, 81 *Warwick Road, Earl's Court, London, S.W.*
1882	Mottram, Richard, *Knott Mill Iron Works, Manchester.*
1871	Müller, Charles Emile, *Middlesbrough.*
1881	Müller, R. W. Maxwell, *Scarboro' and Whitley Rey, Scarboro'.*
1874	Müller, W. H., 12 *Tonhallenstrasse, Düsseldorf, Rhenish Prussia.*
1882	Munday, Edward Miller, *Shipley, near Derby.*
1869	*Murdoch, William, *Barrow Iron Works, Barrow-in-Furness.*
1871	Musgrave, Jno., *Globe Iron Works, Bolton.*
1871	Musgrave, Joseph, *Globe Iron Works, Bolton.*
1878	Naylor, John William, *Wellington Foundry, Leeds.*
1869	*Neesham, George, *Middlesbrough.*
1875	Neilson, George, *Summerlee Iron Works, Coatbridge, N.B.*
1874	Neilson, Hugh, 172 *West George Street, Glasgow.*
1882	Neilson, Hugh, Jun., *Mossend Iron and Steel Works, Mossend, N.B.*
1874	Neilson, James, *Mossend Works, Holytown Station, N.B.*
1869	*Neilson, John, *Summerlee, Coatbridge, N.B.*
1882	Neilson, John A., *Summerlee Iron Works, Coatbridge, N.B.*
1869	*Neilson, Walter, 172 *West George Street, Glasgow.*
1880	Neilson, Walter, Jun., 21 *Hope Street, Glasgow.*
1881	Neilson, Walter, Jun., *Woodfield, Finedon, Wellingboro'.*
1874	Neilson, William, 172 *West George Street, Glasgow.*
1876	New, Alfred James,
1875	Nicholls, Thomas, 76 *Blake Street, Barrow-in-Furness.*

Elected Member	
1881	Nierstrass, N. H., *Hertogenbosch, Holland.*
1877	Norbury, William Edward, *Knott Mill Iron Works, Manchester.*
1873	Nordenfelt, Thorsten, 53 *Parliament St., S.W.*
1869	*Norris, W. G., *Coalbrookdale, Salop.*
1880	Nursey, Perry F., 161 *Fleet Street, London, E.C.*
1869	*Oakes, Thomas H., *Alfreton Works, Alfreton, Derbyshire.*
1880	Ogden, Samuel, *Werneth House, Oldham.*
1875	Ogle, Richard, 4 *St. Ann's Square, Manchester.*
1874	Ongley, Eugene, *Memel, Germany.*
1881	Onions, Edward, *Ormesby Iron Works, Middlesbro'.*
1879	Ormiston, James, *Castlehill Iron Works, Carluke, N.B.*
1872	Ormiston, J. W., *Shotts Iron Company, Shotts, Lanarkshire.*
1882	Osann, Fred., *Düsseldorf.*
1877	Osborn, Samuel, 16 *Philpot Lane, London, E.C.*
1879	Outine, Nicolas, 20 *Rue Froissart, Brussels.*
1878	Owen, David, *Merthyr Tydvil, Glamorganshire.*
1881	Packer, Geo. S., *Hallside Steel Works, Glasgow.*
1878	Page, John, *Wednesfield Park, Wolverhampton.*
1869	*Page, Thomas, *Roway Iron Works, West Bromwich.*
1877	Paget, Arthur, *Loughborough.*
1875	Paget, Berkeley, 2 *Laurence Pountney Hill, London, E.C.*

Elected Member	
1882	Palchondhuri, B. *Orwell Works, Ipswich.*
1880	Palmer, C. A., *Stanton Iron Works, Derbyshire.*
1869	*Palmer, Charles M., M.P., *Jarrow Iron Works, Newcastle-on-Tyne, and* 45 *Grosvenor Square, London, W.*
1878	Palmer, Geo. R., *Palmer's Shipbuilding and Iron Company, Jarrow-on-Tyne.*
1872	Palmer, Jno. Brough, 50 *Clanricarde Gardens, Hyde Park, W.*
1873	Paris, William, *Glasgow Iron Works, Glasgow.*
1881	Park, James, Jun., *Black Diamond Steel Works, Pittsburg, Pa., U.S.A.*
1874	Parke, G. H., *Barrow Rolling Stock Works, Barrow-in-Furness.*
1875	Parker, Jas., *Railway Steel and Plant Co., Newton Heath, Manchester.*
1872	Parker, J. Spear, 297 *Western Bank, Sheffield.*
1879	Parker, William, 2 *White Lion Court, Cornhill, E.C.*
1882	Parkes, Ebenezer, *Atlas Iron Works, West Bromwich.*
1882	Parkes, Henry P., *Tipton Chain, Cable, and Anchor Works.*
1875	Parkyn, William J., *Engineering Works, Dukinfield, near Manchester.*
1881	Parratt, W., 38 *Lyndhurst Road, Peckham, S.E.*
1869	*Parry, John, *Ebbw Vale Iron Works, Newport, Monmouthshire.*
1874	Parsons, P. M., *Melbourne House, Blackheath, Kent.*
1879	Pastor, G., *Ruhrort, Germany.*
1878	Patchett, George, *Manor Road, Halifax.*
1882	Patchett, James, *Shropshire Iron Works, Hadley, Wellington, Salop.*
1869	*Paton, John, *Blaenavon Iron Works, Pontypool, Mon.*
1869	Pattinson, John, 75 *Side, Newcastle-on-Tyne.*
1874	Pattison, John, *Engineer, Naples.*

Elected Member	
1881	Paul, Fred. Wilson, *West Cumberland Works, Workington.*
1876	Peace, Maskell Wm., *Wigan.*
1878	Peake, John Nash, *The Tileries, Tunstall, Staffordshire.*
1871	Pearce, Jno. B., *Hotel Pelham, Boston Co., Boylston, U.S.A.*
1882	Pearce, William, *Care of John Elder & Co., Glasgow.*
1877	Pears, George, *Witton House, Witton-le-Wear, Darlington.*
1872	Pearse, Mountjoy, *Stockton-on-Tees.*
1875	Pearson, Peter, *Dunkirk Iron Works, West Bromwich.*
1873	Pearson, Thos. H., *Dallam Forge Company, Wigan.*
1873	Pease, Edwin L., *Darlington.*
1882	Pease, Henry Fell, *Darlington.*
1869	*Pease, Sir Joseph W., M.P., *Hutton Hall, Guisbrough, and* 24 *Kensington Palace Gardens, London, W.*
1875	Pechin, E. C., 303 *Prospect Street, Cleveland, Ohio, U.S.A.*
1880	Pendred, V., 163 *Strand, London, W.C.*
1881	Pepper, Joseph E., *Clarence Iron Works, Leeds.*
1879	Pernot, Chas., *St. Chamond, Loire, France.*
1877	Perring, Robert Brett, 8 *Essex Street, Manchester.*
1879	*Perry, Thomas J., *Highfields Works, Bilston.*
1873	Petersen, Martin, *Maritime Buildings, Newcastle-upon-Tyne.*
1873	Petin, Jean J. Hippolyte, *Rue Mont Grand* 24, *Marseilles, France.*
1874	Peto, Samuel Arthur, *Plumbago Crucible Works, Battersea, London, S.W.*
1876	Pickering, John, *Railway Carriage and Iron Works, Wishaw, N.B.*
1880	Pickup, Peter, *Towneley Colliery and Fire Clay Works, near Burnley.*

Elected Member	
1874	Piedbœuf, Gustave, *Aix-la-Chapelle.*
1874	Piedbœuf, Louis, *Düsseldorf, Rhenish Prussia.*
1875	Pihfeldt, Olaf, 2 *Bentinck Terrace, Coatham, Redcar.*
1876	Pink, Richard, *Herschel Strasse, S.G., Hanover, Germany.*
1869	*Piper, Joseph, *Cookley Iron Works, Kidderminster.*
1882	Pirie, Lewis J., *Pelham Villa, Clapham Junction.*
1882	Platt, James, *Atlas Iron Works, Gloucester.*
1873	Platt, Samuel R., *Werneth Park, Oldham.*
1874	Plum, T. E. Day, *Mansion House Buildings, London, E.C.*
1881	Poensgen, Carl, *Düsseldorf, Germany.*
1881	Poensgen, Rudolph, *Düsseldorf, Germany.*
1881	Ponthière, Honoré, *Louvain University, Belgium.*
1881	Postlethwaite, Miles.
1872	Potts, John Thorpe, 119 *South Fourth Street, Philadelphia, U.S.A.*
1879	Pourcel, Alexandre, *Terre Noire, France.*
1878	Pratt, Robert Lindsley, *Station Road, Darlington.*
1878	Price, John, *Rose Villa, Jarrow-on-Tyne.*
1874	Price, Joseph, Jun., *Brunswick Foundry, Liverpool.*
1869	*Price, W., *Palmer's Shipbuilding & Iron Co., Jarrow-on-Tyne.*
1871	Prosser, William, 22 *Dean Street, Newcastle-on-Tyne,*
1869	*Putnam, William, *Darlington Forge, Darlington.*
1879	Radford, R. H., 15 *St. James's Row, Sheffield.*
1874	Ramage, John, Jun., 110 *Cannon Street, London, E.C.*

Elected Member	
1869	*Ramsbottom, John, *Fernhill, Alderly Edge, Cheshire.*
1869	*Ramsden, Sir James, *Barrow-in-Furness.*
1869	*Ramsden, W. G., 13 *Tower Chambers, Liverpool.*
1875	Ramwell, William, *Bolton, Lancashire.*
1879	Ransome, Allen, *King's Road, Chelsea, S.W.*
1871	Ransome, Robert Charles, *Ipswich.*
1874	Rapier, Richard C., 5 *Westminster Chambers, London, S.W.*
1882	Rasche, Ludwig, *Eshweiler Ané, near Aix-la-Chapelle.*
1869	*Ratliffe, George, *Mersey Steel and Iron Works, Liverpool.*
1876	Rawlinson, Francis, *Ulverston.*
1874	Rawlinson, Jos., *Lightburn, Ulverston.*
1874	Ray, Edmund, *Lindal Moor Mines, Ulverston.*
1871	Reay, Thomas M., *Spennymoor, County Durham.*
1882	Reay, Thomas P., *Airedale Foundry, Leeds.*
1881	Reed, Chas. H., *Trindon Iron Works, Sunderland.*
1870	Reed, Sir E. J., M.P., *Broadway Chambers, Westminster, S.W.*
1870	Reed, John H., 2 *Pemberton Square, Boston, U.S.A.*
1880	Reichwald, A., *Newcastle-on-Tyne.*
1880	Remaury, M., *Passage Violet, Paris.*
1878	Renton, Benjamin Mann, *Savile Street, Sheffield.*
1881	Reynolds, Jas., 99 *Cromwell Road, South Kensington, S.W.*
1875	Richards, Edward, 2 *St. James's Terrace, Barrow-in-Furness.*
1881	Richards, E., *Barrow Iron and Steel Works, Barrow-in-Furness.*
1869	*Richards, Edwin, *Caldicott Iron Works, Chepstow, Monmouthshire.*

Elected Member	
1869	*Richards, E. Windsor, *Middlesbrough.*
1869	*Richards, J. J., *Atlas Steel Works, Sheffield.*
1869	Richards, Job, 311 *Pershore Road, Edgbaston, near Birmingham.*
1869	*Richards, L., 13 *Charlotte Street, Dowlais.*
1877	Richards, William A., *Llansamlet, Morriston, R.S.O.*
1880	Richardson, Geo., *Oldham.*
1882	Richardson, George, 98 *Westbourne Terrace, London.*
1869	*Richardson, Joseph, *Stockton-on-Tees.*
1869	*Richardson, Thomas, M.P., *West Hartlepool.*
1872	Richardson, T. G., *Killamarsh Forge, Chesterfield.*
1877	Richardson, T. H., *Grove Hill, Middlesbrough.*
1869	*Richardson, W., *Platt Brothers' Works, Oldham.*
1879	Riche, Antoine, *Marchienne-au-Pont, Belgium.*
1881	Richter, Carl, *Königshütte, Katowitz, Silesia.*
1875	Ridehalgh, G. J. M., *Fell Foot, Newby Bridge, Ulverston.*
1869	*Ridley, J. C., *East Queen Street, Newcastle-on-Tyne.*
1877	Ridley, T. D., *Coatham, Redcar.*
1873	Riley, Edward, 2 *City Road, Finsbury Square, London, E.C.*
1874	Riley, Ezra, *Lozell's Grove, Chain Walk, Birmingham.*
1874	Riley, James, 150 *Hope Street, Glasgow.*
1873	Ripley, Hugh, *Acacia, Apperley, near Leeds.*
1876	Ripley, Sir Wm. Henry, Bart., *Acacia, Apperley, near Leeds.*
1882	Ritson, John H. R., *Aberdulais, near Neath, S. Wales.*
1881	Rixon, A. W., 10 *Austin Friars, London.*

Elected Member	
1881	Roberts, W. Chandler, F.R.S., *Royal Mint, London, E.*
1875	Robertson, H., M.P., 13 *Lancaster Gate, London, W., and Palé, Corwen.*
1874	Robertson, James, *Stanley Street Engine Works, Paisley Road, Glasgow.*
1869	*Robinson, J., 7 *Lawrence Pountney Hill, London, E.C.*
1869	*Robinson, John, *Westwood Hall, Leek, Staffordshire.*
1881	Robinson, R., *Hawlish Hall, Bishop Auckland.*
1881	Robinson, Sydney J., *Brightside Steel Works, Sheffield.*
1879	Robinson, T. N., *Mount Faling, Rochdale.*
1870	Robson, Edward, *Kirkleathan, near Middlesbro'.*
1877	Robson, T. S., 57 *Side, Newcastle-on-Tyne.*
1880	Rocour, G., 168 *Boulevard Souvenière, Liège.*
1875	Roe, John P., *Consett, County Durham.*
1873	Rogé, Xavier, *Pont-à-Mousson, Meurthe, France.*
1878	Rogers, John Henry, *South Wales Iron Works, Llanelly.*
1870	Rogerson, J., *Croxdale Hall, Durham.*
1874	Ronna, A., 23 *Rue de Grammart, Paris.*
1882	Roscoe, Dr. Henry, F.R.S., *Victoria University, Manchester.*
1869	*Rose, Henry Fullwood, *Albert Iron Works, Moxley, Wednesbury.*
1875	Roseby, William John, *Commercial Buildings, Leeds.*
1875	Ross, Edward, *M. S. and L. Railway, Marple, Cheshire.*
1869	*Round, B., *Hange Furnaces, Tividale, Tipton.*
1876	Rowbotham, John F., *Ebbw Vale, Monmouthshire.*
1880	Rowe, W. C., *Municipal Workshops, Bombay, India.*
1875	Rummens, Chas., *The Grove, Pinner, Watford, Herts.*

Elected Member

1870 Rummens, Francis,
The Grove, Pinner, Watford, Herts.

1877 Russell, Emil,
Die Direction der Disconts Gesellschaft, Berlin.

1882 Russell, John,
8 *Victoria Chambers, Westminster.*

1882 Sach, Augustus T.,
Beech House, Bowdon, near Altringham.

1877 Sacré, Alfred Louis,
60 *Queen Victoria Street, London, E.C.*

1875 Sacré, Charles,
M. S. and L. Railway Company, Manchester.

1880 Salmon, F. B.,
Birkenhead Forge, Birkenhead.

1882 Salt, Titus,
Saltaire, Bradford, Yorkshire.

1880 Salter, M.,
Workington.

1869 *Samuelson, B., M.P.,
Bodicote Grange, Banbury, and 56 *Prince's Gate, South Kensington, S.W.*

1874 Samuelson, Newton,
Newport Iron Works, Middlesbrough.

1877 Sartoris, Herbert,
Kettering Furnaces, Kettering.

1880 Savignæ, L. de,
Montataire, Oise, France.

1875 Sawrey, John S.,
Fell Side, Pennington, near Ulverston.

1872 Scattergood, J.,
Stour Valley Works, Spon Lane, Birmingham.

1882 Schlink, Joseph,
Friedrich-Wilhelmshütte, Mulheim-on-the-Ruhr, Germany.

1876 Schneider, Henry,
Creusot, France.

1869 *Schneider, Henry William,
Barrow-in-Furness.

1873 Schmitz, E.,
Middlesbrough.

1875 Schofield, C. J.,
Clayton, near Manchester.

1881 Schott, Robert,
Dannemora Steel Works, Sheffield.

1881 Scott, Ernest,
Kersal Edge, Manchester.

1878 Scott, John Fife,
Newcastle-on-Tyne.

Elected Member	
1875	Scott, John Howard, *Nutsford Vale, West Gorton, Manchester.*
1875	Scott, Michael, 9 *Great Queen Street, Westminster, S.W.*
1882	Scott, Ralph G., 33 *Springfield Place, Leeds.*
1878	Scott, William Henry, *Newcastle-on-Tyne.*
1882	Seaman, Fred., *Cliff Villa, Ranmoor, Sheffield.*
1875	Seddon, John Frederick, *Great Harwood, near Accrington.*
1880	Seddon, R. B., *Wigan.*
1877	Seebohm, Henry, *Dannemora Steel Works, Sheffield.*
1881	Seebold, Herr, *Dortmund, Westphalia.*
1874	Sellers, William, 1600 *Hamilton Street, Philadelphia, U.S.A.*
1881	Senior, George, *Pond's Forge, Sheffield.*
1879	Sepulchre, A., *Aulnoye-lez-Berlaiemont, France.*
1878	Sepulchre, François, *Vezin, Belgium.*
1880	Shakell, W. H., *Tudhoe Iron Works, Spennymoor.*
1869	*Sharp, Henry, *Bolton Iron and Steel Works, Bolton.*
1873	Shaw, James, *Cwm Avon, Taibach, Glamorganshire.*
1872	Shaw, William, Jun., *Wolsingham, Darlington.*
1869	*Shield, Clifton, *Reform Club, Pall Mall, London.*
1878	Shinn, William P., *Pittsburg, Pa., U.S.A.*
1874	Siddell, Thomas, *Consett Iron Works, Consett, County Durham.*
1869	*Siemens, C. Wm., D.C.L., F.R.S., 12 *Queen Anne's Gate, Westminster, London, S.W.*
1878	Siemens, Alexander, 12 *Queen Anne's Gate, Westminster, London, S.W.*
1876	Siltzer, John, 4 *Cromwell Houses, South Kensington, London, S.W.*
1875	Silvester, William, *Victoria Foundry, West Bromwich.*

Elected Member	
1874	Simon, Henry, *7 St. Peter's Square, Manchester.*
1880	Simpson, F. F., *Parklane Iron Works, Oldbury.*
1877	Simpson, J. B., *Hedgefield House, Blaydon-on-Tyne.*
1874	Simpson, J. S., *Harrington Iron Works, Harrington, Cumberland.*
1876	Simpson, William W., *Oswaldtwistle Collieries, near Accrington.*
1875	Sinnette, G. M.
1875	Slater, Wm., *Shaw Brook Lodge, Burnage, near Manchester.*
1881	Smith, A. Pye, 16 *Philpot Lane, London, E.C.*
1874	Smith, Charles, *Hematite Steel Works, Barrow-in-Furness.*
1882	Smith, Charles S., 64 *London Road, Leicester.*
1881	Smith, C. Weston, *Landore-Siemens Steel Works, Landore, R.S.O.*
1869	*Smith, E. Fisher, *The Priory Offices, Dudley.*
1882	Smith, Fred., *Caledonia Works, Halifax, Yorkshire.*
1875	Smith, Frederick V., *Bilston.*
1873	Smith, George, *Sun Foundry, Glasgow.*
1882	Smith, G. Jackson, *Clyde Street Works, Sheffield.*
1874	Smith, Henry, *West Cumberland Iron Works, Workington.*
1880	Smith, Jno. Jos., 90 *Cannon Street, London, E.C.*
1869	*Smith, John Stores, *Sheepbridge Iron Works, Chesterfield.*
1882	Smith, Joseph H., *Summerhill, Kingswinford, near Dudley.*
1874	Smith, Josiah, *Hematite Steel and Iron Works, Barrow-in-Furness.*
1869	*Smith, Josiah T., *Hematite Steel and Iron Works, Barrow-in-Furness.*
1874	Smith, Robert, *Castle Hill, Sheffield.*
1876	Smyth, Samuel Richard, 97 *and* 98 *Palace Chambers, Bridge Street, S.W.*

Elected Member	
1876	Smith, Thomas Taylor, *Greencroft Park, Durham.*
1873	Smith, William, *Ferryhill Iron Company, Newcastle-on-Tyne.*
1876	Smith, William, *La Belle, Uddingston, near Glasgow.*
1877	Smith, W. Ford, *Gresley Iron Works, Manchester.*
8616	Snelus, G. J. *West Cumberland Iron and Steel Works, Workington.*
1872	*Sparrow, Arthur, *Preese Manor, Shrewsbury.*
1873	Sparrow, J. W., *Beckminster, Wolverhampton.*
1871	Spencer, Adam, *Eston, Middlesbro'.*
1875	Spencer, Eli, *The Knoll, Fulshaw Park, Wilmslow, Cheshire.*
1869	*Spencer, John, *Phœnix Iron Works, Coatbridge, N.B.*
1882	Spencer, John, *Albion Steel Works, Sheffield.*
1879	Spencer, J. W., *Newburn Steel Works, Newcastle-on-Tyne.*
1870	Spencer, Thomas, *The Grove, Shifnal, Salop.*
1869	*Spencer, Thomas, *The Grove, Ryton, Blaydon-on-Tyne.*
1879	Spielman, Isadore, 40 *Queen Victoria Street, E.C.*
1880	Squire, Edw. L., *Coalbrookdale Iron Works, Shropshire.*
1873	Stanley, J. M., *Elway Hall, Rhyl.*
1881	Stanley, John W., *Tondu Iron Works, Bridgend, Glam.*
1873	Stead, J. E., 5 *Zetland Road, Middlesbrough.*
1874	Steavenson, Addison L., *Durham.*
1873	Steer, Edward, *Castle Iron Company,* 16 *Broad Street, Birmingham.*
1873	Stephens, Frederick C., *Bilbao, Spain.*
1877	Sterne, Louis, 10 *Victoria Chambers, Westminster, S.W.*
1880	Steven, Thos., *Milton Iron Works, Glasgow.*

Elected Member	
1875	Stevens, Warwick Allan, *Darlington Works, Southwark Bridge Road, London.*
1872	Stevenson, Graham, *Airdrie, N.B.*
1874	Stevenson, John, *Barrow Hematite Steel Works, Barrow-in-Furness.*
1869	*Stevenson, John, *Aclam Iron Works, Middlesbrough.*
1873	Stewart, Andrew, 41 *Oswald Street, Glasgow.*
1873	Stewart, James, 41 *Oswald Street, Glasgow.*
1874	Stileman, F. C., 23 *Great George Street, Westminster, S.W.*
1876	Stoddart, Charles John, *Granby House, Parkgate, Rotherham.*
1872	Stoker, F. W., *Moor Iron Works, Stockton-on-Tees.*
1880	Storey, Thomas, *Lancaster.*
1879	Strang, J. H., *Lochburn Iron Works, Glasgow.*
1878	Stranger, William Harry, 23 *Queen Anne's Gate, Westminster, S.W.*
1876	Strick, George Henry, *Amman Iron Works, Swansea.*
1880	Strick, Jno., *Silverdale, North Staffordshire.*
1881	Stubbs, Frederick, 29 *Palin Street, Slade Lane, Manchester.*
1880	Summerhill, James, *Tin Plate Works, Motherwell, N.B.*
1872	Summers, James W., *Globe Iron Works, Staleybridge.*
1872	Sumner, William, *Brazenose Street, Manchester.*
1876	Sutcliffe, F. John Ramsbottom, *Low Moor Iron Works, Bradford, Yorks.*
1872	Sutherland, The Duke of, K.G., *Stafford House, St. James's, London.*
1873	Swan, Edward W., *Middlesbrough.*
1873	Swan, Herbert A., *Middlesbrough.*
1874	Swan, Henry F., *North Jesmond, Newcastle-on-Tyne.*
1869	*Swan, John G., *Cargo Fleet Iron Works, Middlesbrough.*

Elected Member	
1876	Swift, Lionel A., 11 *Lawrence Pountney Lane, E.C.*
1869	*Swindell, J. E., *Cradley Iron Works, Stourbridge.*
1881	Sykes, Robert, 121 *Stamford Street, Staleybridge.*

Elected Member	
1879	Tait, James, *Raisby Hill Lime Works, Coxhoe, County Durham.*
1876	Tannett, John Thomas, *Victoria Foundry, Leeds.*
1869	Tate, John, *Solway Iron Works, Maryport.*
1875	Tatham, John, *Moss Cottage, Rochdale.*
1875	Tatham, Thomas, 102 *Corporation Street, Manchester.*
1880	Taylor, James, 8 *Jeffrey's Square, London, E.C.*
1872	Taylor, John Cordingley, *Oldham.*
1878	Taylor, Osborn, *Panteg Steel Works, Pontypool.*
1876	Taylor, T. A. O., *Clarence Iron Works, Leeds.*
1879	Tennant, Charles, M.P., *Glasgow.*
1875	Thielen, Alex., *Phœnix Iron Works, Ruhrort, Rhenish Prussia.*
1879	Thom, William, *Athol House, Blackburn.*
1881	Thomas, R. B., *Lydbrook, Gloucestershire.*
1878	Thomas, Sydney Gilchrist, 27 *Tedworth Square, Chelsea, S.W.*
1878	Thomas, William, *Bryn Awel, Aberdare.*
1878	Thomas, William Henry, 15 *Parliament Street, S.W.*
1882	Thomlinson, Wm., *South Pittsburg, Tennessee, U.S.A.*
1882	Thompson, Andrew Green, *Bridekirk, Cockermouth.*
1880	Thompson, Cornelius, 24 *Leadenhall Street, E.C.*
1872	*Thompson, George, *Winlaton, Blaydon-on-Tyne.*

Elected Member	
1873	Thompson, Grahame H., 129 *Trongate, Glasgow.*
1882	Thompson, Sir Henry M. M., Bart., *Kirby Hall, York.*
1882	Thompson, James, *Singleton Park, Kendal.*
1869	*Thompson, John, *Clarence Iron Works, Middlesbrough.*
1879	Thomson, Charles, *Calder Iron Works, Coatbridge, N.B.*
1869	Thomson, George, *Ruabon Iron Works, Ruabon, North Wales.*
1878	Thomson, George Frederick, *Pen-y-Bryn, Ruabon, North Wales.*
1882	Thomson, James A., *Clyde Bank Shipyard, Dumbartonshire, N.B.*
1869	*Thomson, J. M., *Calder Iron Works, Glasgow.*
1878	Thomson, John, *Eston Mines, near Middlesbro'-on-Tees.*
1873	Thorburn, John, *Ditton Brook Iron Works, Ditton Brook, Widnes.*
1881	Thorburn, Wm., *Ditton Iron Works, Ditton, Widnes.*
1881	Thornton, John Z., 9 *St. Andrew's Road, Surbiton.*
1881	Thwaites, Edward H., *Vulcan Iron Works, Bradford, Yorks.*
1871	Tinn, Joseph, *Ashton Rolling Mills, Bedminster, near Bristol.*
1874	Todd, Hadden W., *St. Helen's, Lancashire.*
1882	Tomkys, Joseph, *Carr House Iron Works, West Hartlepool.*
1874	Topham, Henry Richard, *Ifield, Prince Arthur Road, Hampstead, N.W.*
1870	Tosh, E. G., *The North Lonsdale Iron and Steel Company, Ulverston.*
1870	Tosh, George, *North Lincolnshire Iron Works, near Brigg, Lincolnshire.*
1881	Tosh, R. George, *North Lincolnshire Iron Works, Brigg, Lincolnshire.*
1879	Tosh, William.
1874	Trasenster, L., *Liège, Belgium.*
1881	Trubshaw, Ernest, *Western Tin Plate Works, Llanelly, South Wales.*

Elected Member	
1880	Tucker, A. E., *Rhymney, Mon., S. Wales.*
1879	Turner, Thomas, Jun., *Suffolk Works, Sheffield.*
1880	Turton, Thos., *Birkenhead.*
1869	*Udall, Thomas, *Care of Thos. B. Udall, Newcastle-under-Lyme, Staffordshire.*
1875	Uhlenhaut, Carl, *Essen, Rhenish Prussia.*
1879	Upton, D., *Codnor Park, Alfreton, Derbyshire.*
1881	Ure, George, *Bonnybridge, Denny, Scotland.*
1874	Valentine, Charles J., *Marshside, Workington.*
1875	Valton, Ferdinand, 20 *Rue le Peletier, Paris.*
1873	Vaughan, Cedric, *Hodbarrow Mines, Millom, Cumberland.*
1879	Vaux, E. P., *Elstree, Herts.*
1869	*Vickers, T. E., *River Don Works, Sheffield.*
1881	Vitoria, His Excellency José Felix, *Bilbao, Spain.*
1869	*Waddington, Joseph, *Iron Foundry, Barrow-in-Furness.*
1878	Waddle, J. R., *Llanelly, Carmarthenshire.*
1870	Wadham, Edward, *Milwood, Dalton-in-Furness.*
1872	Walker, Alfred, *York Railway Plant Works, York.*
1869	*Walker, B., *Goodman Street Works, Leeds.*
1875	Walker, John Scarisbrick, *Pagefield Iron Works, Wigan.*

Elected Member	
1875	Walker, Thomas, *Ridgefield Terrace, Failsworth, Manchester.*
1874	Walker, William, *Saltburn-by-the Sea, Yorkshire.*
1872	Wallace, David, *Glassingall, Dunblane, N.B.*
1882	Wallis, Henry Ellis, M.I.C.E., *St. Stephen's Chambers, Westminster.*
1880	Wallis, Jno., *Kettering.*
1869	*Walmsley, Thomas, *Bolton.*
1875	Walton, John P., *Acomb, Hexham.*
1878	Walton, Joseph J., *Middlesbrough.*
1869	Ward, George, *Bearnett House, Wolverhampton.*
1869	*Ward, Henry, *Priestfield Works, Wolverhampton.*
1878	Ware, Charles William, *Steel Works, Wolsingham, near Darlington.*
1879	Watrand, Charles, *Creusot, France.*
1875	Watson, H. W., Jun., *Burnopfield, Newcastle-on-Tyne.*
1874	Watson, John, *Vane House, Seaham Harbour, Durham.*
1878	Watson, William, *Solway Iron Works, Maryport.*
1876	Webb, F. W., *Chester Place, Crewe.*
1873	Webb, Henry, *Irwell Forge, Bury.*
1872	Webb, Henry A., *Brettell Lane Iron Works, Stourbridge.*
1873	Wedekind, Hermann, 158 *Fenchurch Street, London, E.C.*
1878	Weeks, Joseph D., *Pittsburg, Pa., U.S.A.*
1875	Weild, Edward.
1872	Weir, William, *Gartsherrie Iron Works, Coatbridge, N.B.*
1878	Wellman, Samuel J., *Otis Iron and Steel Company, Cleveland, Ohio, U.S.A.*
1882	Wells, Charles, *Moxley Steel and Iron Works, near Wednesbury.*

Elected Member	
1872	Wendel, Henri de, *Hayange, Lorraine, Germany.*
1872	Wendel, Robert de, *Hayange, Lorraine, Germany.*
1882	Westhead, Thos. C. B., *Couldon House, Stoke-on-Trent.*
1878	Westmacott, Percy, *Benwell Hill, Newcastle-on-Tyne.*
1869	*Westray, John, *Saltburn-by-the-Sea.*
1871	Wheeldon, Frederick R., 16 *Waterloo Road, Wolverhampton.*
1879	Wheelock, Jerome, *Worcester, Mass., America.*
1879	While, J. M., *Darlington Steel Works, Darlington.*
1873	Whitehead, John, Jun., *Elton, near Bury.*
1881	Whitehouse, D., *Abercarn, Newport, Mon.*
1870	Whitham, J., *Perseverance Iron Works, Leeds.*
1878	Whitley, Jno. R., 7 *Poultry, London, E.C.*
1873	Whitley, Joseph, *Railway Works, Leeds.*
1869	*Whitwell, William, *Thornaby Iron Works, Stockton-on-Tees.*
1869	*Whitworth, Sir Joseph, Bart., *Manchester, and Great George Street, London.*
1876	Wicksted, Jos. Hartley, *Care of J. Buckton & Co., Well House Foundry, Leeds.*
1881	Wigzell, Eustace, *Sowerby Bridge, Yorkshire.*
1874	Wild, H. F., *Phœnix Ville, U.S.A.*
1882	Wilkinson, George, *Tividale Sheet Mills, Tipton.*
1877	Wilkinson, T. S., *Smallthorne, near Stoke.*
1870	Willans, Jacob G., 68 *Priory Road, West Hampstead, N.W.*
1878	Willans, John William, *Newlands, Middlesbrough.*
1878	Willett, B., 56 *Rue de Provence, Paris.*
1875	Williams, David, *Pontypool.*

Elected Member

1869 *Williams, Edward,
Cleveland Lodge, Middlesbrough.

1880 Williams, Illtyd.,
Linthorpe Works, Middlesbrough.

1880 Williams, J.,
Ebbw Vale, Monmouthshire.

1880 Williams, John,
Hadley, Wellington, Salop.

1872 Williams, John,
The Green, Wishaw, N.B.

1872 Williams, Nicholas,
Hodbarrow Mines, Millom, Cumberland.

1869 Williams, Richard,
Brunswick Iron Works, Wednesbury.

1872 Williams, Richard Price,
38 *Parliament Street, Westminster, S.W.*

1874 Williams, Robert,
Excelsior Iron Works, Wishaw, N.B.

1869 Williams, Walter,
Wednesbury Oak Iron Works, Tipton.

1877 Williams, Wilfred,
Newhall Works, Birmingham.

1882 Williams, William,
Forest Hall, Swansea.

1877 Williamson, Alex., F.R.S.,
University College, London, W.C.

1871 Williamson, Hugh W.,
Goldendale Iron Works, Stoke-upon-Trent.

1880 Williamson, H.,
Oakhurst, Cockermouth.

1873 Williamson, J. D.,
Cargo Fleet, Middlesbrough.

1877 Williamson, Richard,
Workington, Cumberland.

1879 Williamson, Thos.,
Oakhurst, Cockermouth.

1870 Willman, Charles,
Middlesbrough.

1880 Willwood, Thos.,
Distington Iron Works, Whitehaven.

1869 *Wilson, Alexander,
Dronfield, near Sheffield.

1875 Wilson, Alfred,
Care of Tangyes Steel Co., Soho, Birmingham.

1869 *Wilson, George,
Cyclops Steel Works, Sheffield.

1873 Wilson, George,
Murrayfield House, Murrayfield, Edinburgh.

Elected Member	
1869	*Wilson, Isaac, M.P., *Nunthorpe Hall, Middlesbrough.*
1869	*Wilson, John Frederick, *Tees Side Iron Works, Middlesbrough.*
1882	Wilson, Robert, *Broughton Grange, Carlisle.*
1878	Wilson, T. Crawhult, *Alston House, Alston.*
1873	Wilson, Thomas, *Oaklands, Riding-Mill-on-Tyne.*
1880	Wilson, William, *Lowther Iron Works, Workington.*
1880	Winby, F. C., 1 *College Street, Nottingham.*
1879	Wise, W. L., 46 *Lincoln's Inn Fields, W.C.*
1873	Withy, Edward, *Middleton Shipyard, Hartlepool.*
1882	Wittgenstein, Karl, 7 *Schellinggasse, Vienna.*
1881	Wolfenden, William, *Dronfield, near Sheffield.*
1874	Wood, Charles, *Tees Iron Works, Middlesbrough.*
1873	Wood, George R., *Wishaw, N.B.*
1875	Wood, George, *Westbourne House, Sheffield.*
1871	Wood, John, *Maryport Hematite Iron Works, Maryport.*
1876	Wood, Thomas, *Ebbw Vale Works, Newport, Mon.*
1882	Woodall, John W., *Scarborough.*
1882	Woodcock, Henry, *Clough Hall Iron Works, Stoke-on-Trent.*
1879	Woodcock, H. B., *Low Moor, Bradford.*
1875	Woodhouse, George, *Bolton, Lancashire.*
1877	Worton, John, *Blaenavon Iron Works, Monmouthshire.*
1869	*Wragge, Frederick, *Shelton Bar Iron Works, Stoke-on-Trent.*
1876	Wraith, George Henry, *Tudhoe Iron Works, Spennymoor.*
1875	Wright, Fitzherbert, *Swanwick Hayes, Alfreton.*

Elected Member	
1873	Wright, J. Roper, *Elba Steel Works, Gower Road, near Swansea.*
1872	Wrightson, Thomas, *Teesdale Iron Works, Stockton-on-Tees.*
1871	Würzburger, Philip, *Dalton-in-Furness.*
1882	Wylie, Alan C., 84 *Cannon Street, London, E.C.*
1878	Wynne, Francis George, 4 *The Sanctuary, London, S.W.*
1870	Ybarra, Señor Don José A. de, *Bilbao, Spain.*
1881	Young, E. B., *Laboratory Offices, Arcade Chambers, Newport, Mon.*
1880	Young, James, *Lowmoor Iron Works, near Bradford.*
1872	Young, John, *Phœnix Iron Works, Glasgow.*
1882	Zeitz, Th., *St. Peter's Close, Sheffield.*
1881	Ziane, Jules, 2 *Rue Hotel des Moniaies, Brussels.*

THE END.

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